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(54) Communications systems

(57) A method for upgrading an optical communications system; in which the system comprises a plurality of nodes linked by one or more optical paths, each path for the communication of traffic comprising a single optical channel; in which each node comprises add/drop multiplex (ADM) means for adding and dropping signals in electrical form, and conversion means for converting between electrical and optical form signals output by the ADM means for transmission via a first one of the optical paths; and for converting signals received via a second one of the optical paths for input to the ADM means; the method comprising the steps of installing optical demultiplex means for selecting signals received via the second one of the optical paths according to wavelength for input to the ADM means; installing means for converting the signals output by the ADM means into a first stable narrow wavelength band optical signal; and installing optical multiplex means for guiding the first signal into the first optical path and comprising means for allowing one or more further stable narrow wavelength band optical signals having different wavelengths from the first signal to be added and combined with the first signal into the first optical path.

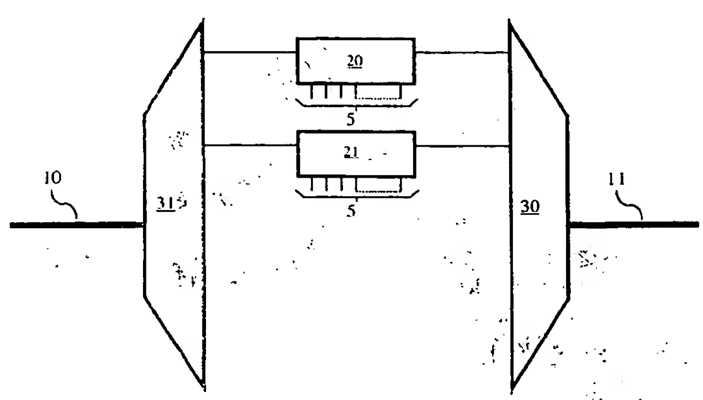

Fig. 3

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Description

[0001] The present invention relates to the field of optical communications systems and in particular to a method for upgrade of such systems.

[0002] Optical communications systems are a substantial and fast-growing constituent of communications networks. The expression "optical communications system", as used herein, relates to any system which uses optical signals to convey information across an optical medium. Such optical systems include, but are not limited to, telecommunications systems and local, metropolitan and wide area networks (LANs, MANs and WANs). Optical systems are described in Gowar, Ed. *Optical Communications Systems,* (Prentice Hall, N.Y.). Currently, the majority of optical communication systems are configured to carry only a single optical channel. In order to signal over this optical channel, a suitably modulated laser is used that emits light in a spectrum the centre wavelength of which is not precisely defined (so-called "grey light"). As a result the channel is allocated a relatively broad spectral band. The optical guide is specified to have a sufficiently low attenuation over this relatively broad spectral band to ensure acceptable signal to noise at the receiver. Here "optical guide" is used to describe any suitable optical transmission medium, including optical fibres and optical waveguides.

[0003] There is a need to access at nodes of the communications system , which may be comprised of, for example, rings, interconnected rings or meshes, the information carried in such optical guides so that individual messages may be routed to the correct destinations. To this end each node will contain switching circuitry. An economical form of switching circuitry for such nodes is the add-drop multiplexer (ADM). An ADM provides low cost access to all or part of the time division multiplexed (TDM) traffic forming a data stream passing along a communications link, such as an optical guide. The traffic passing through the ADM does so via "line ports" connecting to the bearer. Data or messages passing along the telecommunications bearer are selectively time division demultiplexed by switching circuitry in the ADM and the selected messages or message parts are passed via so-called tributary ports to their destination. Similarly, data or messages for adding to the telecommunications bearer are fed to the ADM via the tributary ports and are time division multiplexed into the message stream by the ADM switching circuitry. This switching and multiplexing function is performed in the electrical domain. In order to interface to an optical communications link, the nodes include optical to electrical converters (i.e. photodetectors) and electrical to optical converters (i.e. laser signal generators).

[0004] The continuing and rapid increase in the amount of data traffic carried by telecommunications operators has led to an increasing need to improve the data carrying ability of existing networks. A conventional TDM communications system may be upgraded purely by increasing the TDM data rate of components of the link. This may call for the electronics equipments to be modified but permits the installed fibre link to be retained and used, thereby saving costs of additional fibre installation (which may be considerable). Current technology imposes strict limits on the gains available from increasing the TDM data rate due to optical sensitivity limitations in the receiver, safety limits to protect, e.g. maintenance workers, which restrict the amount of launch power which can be used, chromatic dispersion causing "eye-closure" in the digital signal at the receiver and other propagation impairments which depend upon TDM signalling rate

[0005] The optical communications link typically comprises optical fibre. The capacity of a dual fibre line system (in which one fibre is used to carry traffic in each direction) can be increased by introducing 'single fibre working' into each of the fibres. Conventionally traffic flows in the fibre in one direction only. By introducing a directional optical coupler eg a fused twisted optical fibre pair coupler, at each end of a fibre, signalling may be effected in both directions on the one fibre. Thus the traffic previously passing on two fibres can be compressed onto one fibre and the second fibre then used as a separate line. This system is impaired by back scattering at the launch components and in the fibre itself and by beating between the signals from the two transmitter lasers (one at each end) and can be improved by selecting lasers with disparate wavelengths. Improved performance also accrues if the signalling wavelengths are chosen such that the receivers can be designed to be insensitive to the 'other' wavelength. This latter procedure was the start of using wavelength selection towards capacity upgrade of fibre systems which has led on to wavelength division multiplexing discussed below.

[0006] The capacity of a single fibre line system can be increased by means of wavelength division multiplexing. In a wavelength division multiplexed (WDM) system there is a plurality of optical signals each signal having a spectrum whose centre wavelength is constrained within a narrow spectral band, the acceptable pass band of the fibre being divided up into a multiplicity of such narrow spectral bands. By upgrading a single channel system to a two-channel WDM system i.e. replacing the single "grey" channel with two narrow band channels its capacity may be increased. Whilst the TDM up-grade potential is strictly limited, the use of multichannel WDM has a much greater potential for increased data rates with 8, 16, 32 and more channel WDM systems being proposed.

[0007] However replacing a single channel photonic system with a WDM system supporting many different channels requires the replacement of a considerable amount of equipment at each node with new WDM equipment. This is expensive and may involves considerable over-provision of capacity bearing in mind that a doubling of capacity is often all that is required of a particular upgrade. There is therefore a need for a method

for incrementally upgrading the traffic handling capacity of an optical communications system.

[0008] The present invention provides a method for upgrading an optical communications system; in which the system comprises a plurality of nodes of which two are linked by a single optical path for the communication, from the node at a first end of the optical path to the node at the other end of the optical path, of traffic comprising a single optical channel; in which each node comprises add/drop multiplex (ADM) means for adding and dropping signals in electrical form, in which the node at the first end of the optical path comprises a single light source for converting from electrical to optical form signals output by the ADM means for transmission via the optical path; and in which the node at the other end of the optical path comprises a photodetector for converting signals received via the optical path for input to the ADM means; the method including the steps of replacing the single light source at the first end of the optical path with a plurality of stable narrowband light sources having mutually different wavelengths, installing at the first end of the optical path optical multiplex means for multiplexing the outputs of the plurality of stable narrowband light sources into the optical path; replacing the single photodetector at the other end of the optical path with a plurality; installing at the other end of the optical path optical demultiplex means for demultiplexing a like plurality of received optical channels, whereby each of the plurality of optical channels is converted to electrical signals and applied to ADM means.

[0009] The present invention also provides a method for upgrading an optical communications system; in which the system comprises a plurality of nodes linked by one or more optical paths, each path for the communication of traffic comprising a single optical channel; in which each node comprises add/drop multiplex (ADM) means for adding and dropping signals in electrical form, and conversion means for converting between electrical and optical form signals output by the ADM means for transmission via a first one of the optical paths; and for converting signals received via a second one of the optical paths for input to the ADM means; the method comprising the steps of installing optical demultiplex means for selecting signals received via the second one of the optical paths according to wavelength for input to the ADM means; installing means for converting the signals output by the ADM means into a first stable narrow wavelength band optical signal; and installing optical multiplex means for guiding the first signal into the first optical path and comprising means for allowing one or more further stable narrow wavelength band optical signals having different wavelengths from the first signal to be added and combined with the first signal into the first optical path.

[0010] According to a preferred embodiment, the present invention provides a method comprising switching individual time division multiplexed messages between wavelength multiplexed channels of the optical communications system, comprising the steps of arranging switch means comprising a plurality of add drop multiplex (ADM) means, one per wavelength multiplex channel; in which each ADM means comprises tributary means, the method comprising the steps of interconnecting the ADMs means via the tributary means.

[0011] According to a preferred embodiment the present invention provides a method comprising switching individual time division multiplexed messages between a plurality of streams of time division multiplexed data; in which each stream of time division multiplexed data is comprised in a channel of the wavelength multiplexed optical communications system, the method comprising the steps of providing one or more of the nodes with a plurality of add drop multiplex (ADM) means, one per WDM signal; providing each ADM means with tributary means and interconnecting the ADM means via the tributary means.

[0012] Embodiments of the invention will now be described by way of example with reference to the drawings in which:

Figure 1 shows part of a single-channel photonics communications network;
Figure 2 shows the network of Figure 1 partially upgraded according to an embodiment of the present invention;
Figure 3 shows the communications network of Figure 2 upgraded further according to a further embodiment of the present invention;
Figures 4 to 9 show alternative arrangements according to further embodiments of the present invention.

[0013] Figure 1 shows a node of an optical communications network comprising a conventional, electrical add/drop multiplexer (ADM) 1 with two line ports: port 2 facing east and port 3 facing west; for simplicity each line port is shown as being uni-directional (with traffic flowing from East to West), although normally these are bidirectional with each direction occupying a separate fibre. In addition ADM 1 has a plurality of tributary connections 5, connected to tributary port 6. The ADM also comprises switching means (not shown) for adding or dropping selected parts of the datastream passing through the ADM. The output from the West port 6 passes through an electrical to optical interface 8 (e.g. a laser). The input line to East port 5 passes through an optical-to-electrical converter 9 (e.g. a photodiode). The communications network in which the ADM 1 is connected transports signals in the optical domain between successive nodes along optical links (e.g. optical fibres) of which two are shown in Figure 1 (10, 11). In an alternative embodiment (not shown), optical fibres are used in pairs for each link advantageously allowing direct bidirectional communication between each node of the network. In the case where the nodes are arranged in a ring configuration the use of these fibre pairs also provides

a protection path in the event of damage to one of the fibres.

[0014] In Figure 2 the conventional, electrical ADM 1 of Figure 1 together with electrical/optical interfaces 8 and 9 are represented by a single, coloured optically-interfaced add/drop multiplexer (COIADM) block 20. Hence the line inputs and outputs to the COIADM 20 are in the optical domain. It is important to note that all switching in the COIADM actually takes place in the electrical domain as in the case of the conventional ADM 1. The main difference between the arrangement of Figure 2 from that of Figure 1 lies in the optical/electrical interfaces. Whereas the electrical to optical converter 8 of Figure 1 use a low-cost "grey" laser i.e. a laser generating an output with a centre wavelength designed to lie in the low loss region of the fibre within a relatively wide spectral range, the optical to electrical converter of COIADM 20 comprises a precision laser emitting light with a centre wavelength constrained to lie within a comparatively narrow spectral range. Such precision lasers are often referred to as "coloured". Hence the COIADM 20 of Figure 2 can function in a similar way to the arrangement of Figure 1 in communicating via a single optical channel across the optical links 10 and 11. Although no increase in traffic is achieved at this stage, it is to be noted that the COIADM is now using only a small fraction of the available spectrum, i.e. of the capacity of optical links 10 and 11.

[0015] Figure 3 shows the COIADM 20 of Figure 2 now connected to the optical links 10 and 11 via optical demultiplexer 30 and optical multiplexer 31 (e.g. 16 or 32 port diffraction grating type multiplexers having 3dB insertion loss per channel). Optical demultiplexer 30 acts to divide up optical signals received from link 11 according to their wavelength and to feed signals of the appropriate wavelength to COIADM 20, i.e. signals matched to the specific transmission band of the precision laser of COIADM 20. Optical multiplexer 31 acts to combine signals on various wavelengths received at its input onto the single optical link 10 at its output. Hence if the laser of COIADM 20 is selected to produce light concentrated at a wavelength λ_1 of the spectrum, optical demultiplexer 30 will be arranged to pass radiation with a spectrum centred around λ_1 from optical link 11 to the photodetector of COIADM 20 and no other wavelength channels. Hence COIADM 20 receives and transmits only the _λ_1 WDM channel. In addition to the first COIADM 20, the arrangement of Figure 3 has a second COIADM 21 which is connected between optical demultiplexer 30 and optical multiplexer 31 in parallel with COIADM 20. Second COIADM 21 is identical to COIADM 20 except that, in COIADM 21 the precision narrow band laser provided emits radiation in a different part of the spectrum (say λ_2). COIADM 21 is connected at its input to a second output from optical demultiplexer 30 that provides light received from optical link 11 in the λ_2 part of the spectrum and no other colours. Both COIADMs are provided with a plurality of tributaries 5. Messages input to COIADM 20 via tributaries 5 will therefore be transmitted through the communications network on a first WDM channel (i.e. the λ_1 channel) whilst messages input on tributaries 5 to COIADM 21 will be transmitted through the optical communications network on a different WDM channel (i.e. the λ_2 channel) via the same fibre links 10, 11 that were previously used (in the arrangements of Figures 1 and 2) for a single channel. Hence the traffic carrying capacity of the optical communications network has been doubled with a minimum of extra hardware.

[0016] Advantageously, where a protection path is available, as described above, the upgrade of the network, as described above with reference to Figure 3, may be achieved whilst avoiding significant disruption to traffic as follows. To upgrade the network the protection (i.e. unused) path is first upgraded as described and then the traffic is switched quickly to it, so as to cause the minimum of disruption to the traffic. The original, working path is then upgraded in turn.

[0017] If at some later stage the increase in data traffic makes a further upgrade of the traffic handling capacity of the optical communications network desirable, this may be simply and economically achieved by adding a further COIADM to each node of the optical communications network between which the additional traffic handling capacity is required. This third COIADM (not shown) would simply connect to a third output of demultiplexer 30 and the corresponding input on optical multiplexer 31. As each output of optical demultiplexer 30 selects light from a different part of the spectrum, the signals seen by the third COIADM will comprise a further WDM channel distinct from the Aλ_1" and Aλ_2" WDM channels used by the first two COIADMs 20 and 21. The third COIADM will be provided with a precision laser that emits radiation in a narrow band in a different part of the spectrum to those of COIADMs 20 and 21, the narrow band corresponding to the band selected by optical demultiplexer 30 at the third output port thereof.

[0018] Advantageously, once the original communications network has been upgraded to include the optical demultiplexer 30 and optical multiplexer 31 further upgrades of the system may be simply and economically achieved without causing any noticeable disruption to traffic. All that is required is to provide a new COIADM with an appropriate precision laser to each switch node between which extra traffic is to be transported and to connect said new COIADM to the appropriate spare port provided on each of demultiplexer 30 and multiplexer 31.

[0019] Demutiplexer 32 and multiplexer 30 may be installed at the initial >optical= upgrade stage so that any number up to 32 and beyond of additional connections are available for the provisioning of additional COIADMs . This incurs some expense at the initial upgrade stage, the benefit from which will rise in due time as further COIADMs are fitted in response to rising traffic demands.

[0020] Figures 4(a)and (b) show an alternative arrangement to that shown in Figure 3 in which the demultiplexer/ multiplexer 30, 31 are dispensed with. Advantageously, according to the embodiment of Figures 4 (a) and (b) a "daisy chain" upgrade sequence is provided according to which extra components may be added only when extra capacity is required. The system of Figure 4 supports unidirectional working with information flowing from East to West, as in Figure 3. With reference to Figure 4(a), demultiplexer/ multiplexer 30, 31 are replaced by low-cost three-port passive optical components 40, 41 (e.g. thin film dielectric filters) having a narrow-band select function. Filter 40 receives at a first port optical input signals from optical guide 11. Filter 40 selects signals in a narrow spectral band from the input signals for output at a second port feeding the East line input port of COIADM 20 and passes input signals outside of the narrow spectral band to a third port feeding optical guide 13 provided for future upgrades. Optical guide 13 is shown as a "dead-end" or tail in Figure 4(a) and signals passed to it by filter 40 are effectively discarded. Referring now to optical filter 41, this is similar to filter 40 but is configured differently. The input to filter 41 comprises the narrow band optical signal output by COIADM 20 at the West line port thereof. This signal is passed by filter 41 to optical guide 10 via a second, output port. As with filter 40, filter 41 has a third port connected to an optical guide tail 12 provided for future upgrades. The third port of filter 41 is arranged so that optical signals received from optical guide 12 will be combined with the narrow band signals from COIADM 20 and the combined signal output from the second, output port to optical guide 10.

[0021] Advantageously, where a protection path is available, as described above, the upgrade of the network, as described above with reference to Figure 4(a), may be achieved whilst avoiding significant disruption to traffic as follows. To upgrade the network the protection (i.e. unused) path is first upgraded as described and then the traffic is switched quickly to it, so as to cause the minimum of disruption to the traffic. The original, working path is then upgraded in turn

[0022] Referring now to Figure 4(b), we see the system of Figure 4(a) now upgraded with the addition of a second COIADM 21. Advantageously, this upgrade is achieved without any disruption to traffic on optical guides 10 and 11, as follows. New COIADM 21 is connected between optical filters 42 and 43 that function in a similar way to filters 40 and 41, described above, respectively. The only difference in their function is that, while filters 40 and 41 select and combine signals, respectively, in a first wavelength band, e.g. "λ_1" corresponding to a first WDM channel, filters 42 and 43 select and combine signals, respectively, in a second wavelength band, e.g. "λ_2" corresponding to a second WDM channel. As with filters 40 and 41 in Figure 4(a), filters 42 and 43 connect at the third ports thereof to optical guide tails 15 and 14, respectively, provided for future upgrades.

[0023] When further requirements for transmission traffic capacity make additional COIADM equipment necessary further pairs of filter can be provided with this additional COIADM and can be installed without further disruption to the traffic.

[0024] In figures 5 and 6 illustrate arrangements for bidirectional communication over a single fibre ("single fibre working"). Referring to Figure 5, this shows a single fibre arrangement used with the 'daisy chain' upgrade strategy described above with reference to Figure 4. Features common to Figure 4(b) are given the same reference numerals and will not be described further here. Passive optical components 33 and 34 are provided with at least three ports for separating traffic travelling in different directions on the fibre path 10, 11. These are band discrimination devices that act to pass light of a first spectral band in one direction and to pass light of a different spectral band in the opposite direction. In practice the first band may consist the 1.3 nanometre (nm) waveband used for carrying a plurality of WDM channels and the second band may consist of the 1.5 nm band used for carrying a further plurality of WDM channels. An optical directional coupler (e.g. a thin film dielectric filter) serves this function. The operation of the system of Figure 5 will now be described, initially as a unidirectional system. Considering first traffic passing, as before, from West to East (i.e. in the direction of arrow 36): band discriminator 34 receives at a first input port optical input signals from optical guide 11. Band discriminator 34 selects signals in a first broad spectral band (e.g. the 1.3 nm band) from the input for output at a second port feeding the input ports of filters 40, 42. Band discriminator 34 allows signals of the second broad spectral band (e.g. the 1.5 nm band) to pass between the input port and a third port connected to optical guide 17. Optical guide 17 is shown as a tail and, in the unidirectional mode, signals passed to it by filter 40 are effectively discarded. Referring now to band discriminator 33, this is similar to band discriminator 34 but is configured differently. The East input port of band discriminator 33 is connected to the West output ports of filters 41, 43. Band discriminator 33 is arranged to pass signals comprised in the first broad spectral band between the first port thereof and a second, output port thereof connected to optical guide 10. As with band discriminator 34, band discriminator 33 has a third port connected to an optical guide tail 16 provided for bidirectional working. The third port of band discriminator 33 is arranged to pass optical signals comprised in the second broad spectral between the second and third ports thereof, i.e. between optical guides 10 and 16.

[0025] The operation of the system of Figure 5 will now be described as a bidirectional system. As will be evident from the above description of the unidirectional operating mode, signals of the second broad spectral band arriving at the third West port of band discriminator 33, i.e. in the direction of arrow 35, will pass there-

through to emerge from the second port thereof and hence into optical guide 16. Similarly, signals of the second broad spectral band arriving at the second port of band discriminator 34 from optical guide 17 will pass there-through to emerge from the first East port thereof and hence into optical guide 11. In order to achieve bidirectional working, a second "daisy chained" ADM arrangement (not shown but, e.g. as in Figure 4(b)), is added between optical guides 16 and 17 of the system of Figure 5. This second ADM arrangement differs from that shown connected between band discriminators 33 and 34 of Figure 5 in that signals flow in the opposite direction, i.e. from West to East. As with the system of Figure 4, described above, further COIADMs may be added to either Adaisy chain @ as required. Hence, advantageously, a fully bidirectional multi-channel single fibre working ADM system may be created and incrementally upgraded from a basic, single channel unidirectional system with minimum disruption to traffic.

[0026] According to an alternative embodiment of the present invention, a thin film or multilayer dielectric filter can be used to separate altemate WDM channels into two "combs" (i.e. series of spaced WDM channels). A first comb can be assigned to carry East traffic and the other to West traffic

[0027] Figure 6 shows a bidirectional multi-channel single fibre working ADM system according to a further embodiment of the present invention. Features common to Figure 5 are given the same reference numerals and will not be described further here. However, some extra description is given below in view of the different arrangement of the elements of Figure 6 compared with earlier figures. Whereas earlier figures showed a single node (comprising one or more COIADMs connected to East and West optical guides of a communications link, Figure 6 shows one such optical communications link 10 connected between two logically adjacent nodes, one node comprising band discriminator 34 and COIADM 50, the other node comprising band discriminator 33 and COIADM 55. Unlike earlier representations of COIADMs, the COIADMs 50 and 55 are bidirectional, each comprising an electrical to optical interface 8 (e.g. a laser) and an optical-to-electrical converter 9 (e.g. a photodiode) per line port (one port shown). Hence a bidirectional connection is shown between the East line port of COIADM 50 via band discriminator 34, single optical guide 10 and band discriminator 33 to the West line port of COIADM 55. As before, each of ADMs 50, 55 also comprises a plurality of tributary connections (not shown) connected to tributary port (not shown) and switching means (not shown) for adding or dropping selected parts of the datastream passing through the ADM.

[0028] In contrast to the systems of Figures 4 and 5, the system of Figure 6 uses optical demultiplexers 30 to distribute multiple spectrally separate optical signals received from optical link 10 (via one of band discriminators 34 and 33) between COIADM 50 or 55 (as the case may be) and, via links 52 or 54 (as the case may be), a plurality of further COIADMs (not shown). In a similar way, the system of Figure 6 uses optical multiplexers 31 to concentrate onto optical link 10 (via one of band discriminators 34 and 33) multiple spectrally separate optical signals received from COIADM 50 or 55 (as the case may be) and, via links 51 or 53 (as the case may be), from the plurality of further COIADMs (not shown). The optical demultiplexers 30 and optical multiplexers 31 may be collocated with one of the COIADMs, as shown, or separately accommodated. The plurality of COIADMs may be collocated or physically separated according to space constraints and/ or the geographical distribution of users.

[0029] Note that the directional coupler function, described above with reference to Figure 4, can be integrated into the multiplexers/ demultiplexers if Bragg Grating types and Waveguide types, eg as taught by M. Smit are deployed.

[0030] As with the previous embodiments, to upgrade with small interruption to the traffic, equipment upgrade may be carried out on the protection route not currently carrying traffic (where available). Additional WDM paths are provided with the introduction of the multiplexer and demultiplexer into the optical path. Modifications to give duplex operation (bidirectional traffic) may be made at this time.

[0031] Figure 7 shows a further embodiment of the present invention. Features common to earlier figures are given the same reference numerals and will not be described further here. Band discriminators 34, 84, 86, 88 (eg thin film dielectric filters) are similar units except that each selects a different optical spectral band for passing through to demultiplexers 30 or optical band amplifier 111, as the case may be. Band discriminators 33, 83, 85, 87 (eg thin film dielectric filters) are similar units except that each selects a different optical spectral band for passing through from multiplexers 31 or optical band amplifier 111, as the case may be. In fact, as illustrated by the optical channel amplifiers 110, demultiplexers 30, multiplexers 31 and 33, 83, 85, 87 are all bidirectional devices such that their function depends on the way they are connected rather than their internal structure. Hence COIADM 21 could be configured to pass signals from East to West or vice versa (or both). Where some optical spectral channels received via optical links 10 and 11 are not to be switched (added or dropped) at the present node, they are advantageously passed through the node via a suitable optical amplifier 110 (eg an Erbium doped fibre amplifier or a semiconductor optical amplifier) connected between the relevant ports of multiplexer/ demultiplexers 30, 31. As shown, amplifier 110 provides an amplified through path for a WDM channel. Where some entire optical spectral bands received via optical links 10 and 11 are not to be multiplexed/ demultiplexed or switched (added or dropped) at the present node, they are advantageously passed through the node via a suitable optical amplifier 111 connected

between the relevant ports of band discriminators 33, 83, 85, 87, 34, 84, 86, 88. Optical amplifier 111 may be of similar type to amplifier 110 or specially designed to be suitable for several WDM channels and possibly arranged to have a similar gain independent of the number of WDM signals at its input. 104 to 106 are optical demultiplexer and multiplexer pairs

[0032] Advantageously, connections between ports of demultiplexers 30, multiplexers 31 (i.e. via COIADMs) need not connect corresponding ports but may be staggered as illustrated by the connection to COIADM 21. The electrical to optical interface of COIADM 21 would need to be selected to match the waveband accepted by the relevant input port to multiplexer 31. Such staggered connection provides a simple and flexible means of channel swapping, or wavelength conversion whereby a signal received on a first WDM channel may be output on a different channel.

[0033] An optical space switch 113 (eg such as the thermally activated silica waveguide array switch described by K.Okamoto Tutorial ECOC=98 20Sept Madrid 1998) is connected to the demultiplexed ports of a demultiplexer 31 to give the capability of selecting a particular COIADM and therefore the wavelength (optical channel) to be taken to and over the next fibre segment. This provides additional protection against failures in equipment eg if COIADM 23 has failed an alternative COIADM connected to an output of space switch 113 could be selected and the traffic routed thereby.

[0034] Figure 8 shows a part of a switching node according to the present invention. In Figure 8 the ADMs 20, 21...2n of a node are shown in more detail. In particular, the tributary connections 5 are shown separated into two sub-groups. A first sub-group 311, 312, 313 from first ADM 20 are taken to the next ADM 21, thus allowing interchange of demultiplexed messages therebetween. A second sub-group 310 from first ADM 20 function as before to communicate demultiplexed messages to users and to input messages from users to the ADM for multiplexing.

[0035] In a similar way a sub-group 321, 322, 323 from second ADM 21 are taken to third ADM (not shown). This is repeated so that each ADM is interconnected via a sub-group of tributary connections to the next ADM until the penultimate ADM (not shown) has tributary connections 3(n-1)1, 3(n-1)2, 3(n-1)3 taken to the last ADM 1n of the node.

[0036] According to this so-called "daisy chain" arrangement, each ADM is arranged to pass on messages received from an adjacent ADM via the tributary connections but intended for another ADM further along the "daisy chain" until that destination ADM is reached. On receiving a message via the tributary connections that is intended for a channel handled by that ADM, the ADM will remultiplex it into the message stream for that channel in a similar way to messages received from users via conventional tributary inputs.

[0037] Hence the node of Figure 8 advantageously allows messages from a first WDM channel to be converted to the electrical domain, demultiplexed using the conventional ADM circuitry and to be passed in its demultiplexed, electrical state to a selected other one of the ADMs of that switch node where it is multiplexed into the data stream of a second WDM channel using the conventional ADM circuitry and converted back into the optical domain in the appropriate waveband for the second WDM channel. Advantageously, messages of any level of granularity handled by the ADMs may be switched in this way.

[0038] Although the illustration of Figure 8 shows a "daisy chain" interconnection of the ADMs of a node, other interconnection patterns may be used according to preferred embodiments of the present invention, including a ring, full mesh or partial, "nearest neighbours" mesh. This interconnection may be implemented within a node in such a way that effective interconnectivity can be achieved in an incremental fashion as the equipping of a node progresses to accommodate increased traffic demand, e.g. by adding extra ADMs to a node as and when required.

[0039] According to the embodiment of Figure 9, the relevant tributaries could be interconnected via a separate switch unit 18 designed to provide the required switch connections and capacity. Switch 18 could also be incrementally upgradable Extra provision will be required to manage this new switch element within the network management system.

[0040] It may be desirable not to collocate all the ADMs of a node because of space constraints in current exchange buildings so that the interconnection of the tributaries 311, 312 313 , etc of Figures 8 or 9 may entail the distribution of digital data over relatively long distances. According to a further preferred embodiment of the present invention, optical fibre interconnections utilising WDM principles are applied to the interconnection of the ADM tributaries. As TDM rates and the number of tributary interconnections increase, switch 18 may provide optical matrix switching to switch messages between interconnected tributaries, according to a further embodiment.

[0041] Although described above substantially with reference to unidirectional optical paths, the present invention applies equally to the case of upgrading a bidirectional link in which a single optical channel using grey light is used in each direction. Each direction of the link may be upgraded, as described above with reference to a single direction.

Claims

1. A method for upgrading an optical communications system; in which the system comprises a plurality of nodes of which two are linked by a single optical path (10, 11) for the communication, from the node at a first end of the optical path to the node at the

other end of the optical path, of traffic comprising a single optical channel; in which each node comprises add/drop multiplex (ADM) means (1) for adding and dropping signals in electrical form, in which the node at the first end of the optical path comprises a single light source (8) for converting from electrical to optical form signals output by the ADM means for transmission via the optical path; and in which the node at the other end of the optical path comprises a photodetector (9) for converting signals received via the optical path for input to the ADM means;
the method including the steps of replacing the single light source at the first end of the optical path with a plurality of stable narrowband light sources having mutually different wavelengths, installing at the first end of the optical path optical multiplex means (31, 41, 43) for multiplexing the outputs of the plurality of stable narrowband light sources into the optical path; replacing the single photodetector at the other end of the optical path with a plurality; installing at the other end of the optical path optical demultiplex means (30, 40,, 42) for demultiplexing a like plurality of received optical channels, whereby each of the plurality of optical channels is converted to electrical signals and applied to ADM means.

2. A method for upgrading an optical communications system; in which the system comprises a plurality of nodes linked by one or more optical paths (10, 11), each path for the communication of traffic comprising a single optical channel; in which each node comprises add/drop multiplex (ADM) means (1) for adding and dropping signals in electrical form, and conversion means (8) for converting between electrical and optical signals output by the ADM means for transmission via a first one of the optical paths (10); and (9) for converting signals received via a second one of the optical paths (11) for input to the ADM means;
the method comprising the steps of installing optical demultiplex means (30, 40, 42) for selecting signals received via the second one of the optical paths according to wavelength for input to the ADM means; installing means for converting the signals output by the ADM means into a first stable narrow wavelength band optical signal; and installing optical multiplex means (31, 41, 43) for guiding the first signal into the first optical path and comprising means for allowing one or more further stable narrow wavelength band optical signals having different wavelengths from the first signal to be added and combined with the first signal into the first optical path.

3. The method as claimed in Claim 2 comprising the steps of installing further ADM means, selecting further signals received via the second one of the optical paths according to wavelength for input to the further ADM means, installing means for converting the signals output by the further ADM means into further narrow wavelength band optical signals having different wavelengths from the first and combining the first and the further narrow wavelength band optical signals into the first optical path.

4. The method as claimed in any above claim comprising the step of demultiplexing the signals received via the single or the second optical path in a series of sequential steps.

5. The method as claimed in any above claim comprising the step of combining the first narrow wavelength band optical signal with the one or more further narrow wavelength band optical signals in a series of sequential steps.

6. The method as claimed in any above claim comprising installing an optical multiplexer and demultiplexer each having a multiplicity of spectrally distinct narrow band ports to form one or more additional optical paths through a segment of the optical communications system, each additional optical path for upgrading the optical communications system without further interruption to traffic therein.

7. The method of claim 6 comprising using an optical multiplexer and demultiplexer each comprising a first port for the selection of a narrow wavelength band channel comprising the first one of the demultiplexed signals; the optical multiplexer and demultiplexer each comprising a second port for selection of a plurality of further wavelength band channels; each further channel for upgrading the communications system without further interruption to traffic therein.

8. The method of any one of claims 6 and 7 comprising linking multiplexer ports with demultiplexer ports via signal amplification means.

9. The method of claim 6 comprising linking multiplexer ports with demultiplexer ports via space switch means.

10. The method of any above claim comprising using broad band optical directional couplers for single fibre working over one or more of the optical paths.

11. The method of any of claims 1 to 9 together with the use of single fibre working over one or more of the optical paths using different wavelengths channels to communicate in each direction.

12. The method of any above claim using a spectrum comb interleaver to separate alternate channels into two sets, a first set for communication in a first

direction through the optical communications system and a second set for communication in the opposite direction there through.

13. The method of any above claim in which the demultiplexed signals comprise time division multiplexed (TDM) data streams.

14. The method of claim 13 in which different ones of the demultiplexed signals comprise different rate and/or format TDM data streams.

15. The method of any above claim comprising controlling the ADM means by a Network Management System.

16. In a protected optical communications network, upgrading the protection path according to the method of any above claim then switching traffic from the working path to the protection path then upgrading the working path according to the method of any above claim.

17. The method as claimed in any above claim as dependent from Claim 2 in which the first and second optical paths are the same path.

18. The method of any above claim comprising switching individual time division multiplexed messages between a plurality of streams of time division multiplexed data; in which each stream of time division multiplexed data is comprised in a channel of the wavelength multiplexed optical communications system, the method comprising the steps of providing one or more of the nodes with a plurality of add drop multiplex (ADM) means, one per WDM signal; providing each ADM means with tributary means and interconnecting the ADM means via the tributary means.

19. The method of any one of claims 1 to 17 above comprising switching individual time division multiplexed messages between wavelength multiplexed channels of the optical communications system, comprising the steps of arranging switch means comprising a plurality of add drop multiplex (ADM) means, one per wavelength multiplex channel; in which each ADM means comprises tributary means, the method comprising the steps of interconnecting the ADMs means via the tributary means.

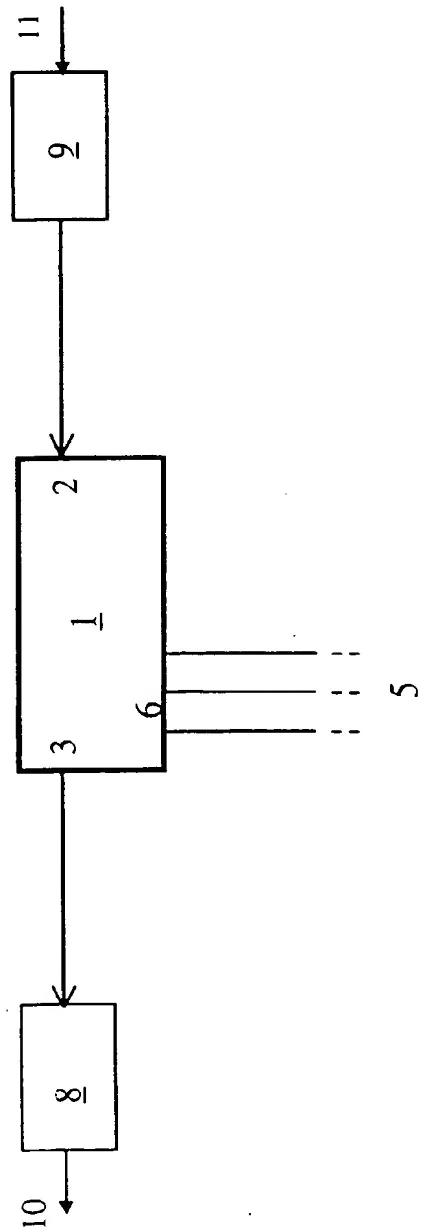

Fig. 1

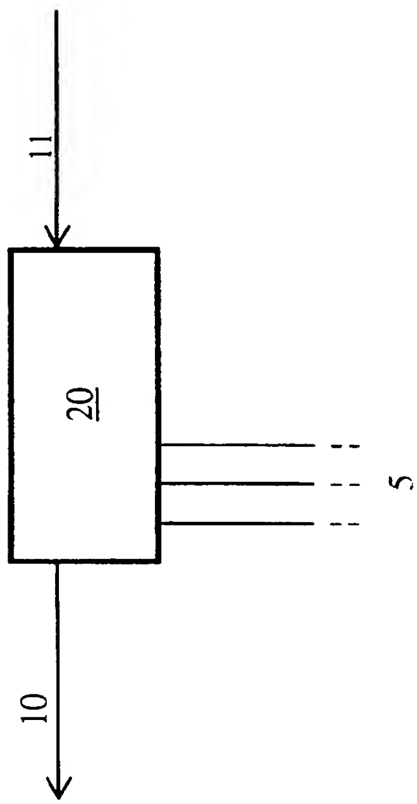

Fig. 2

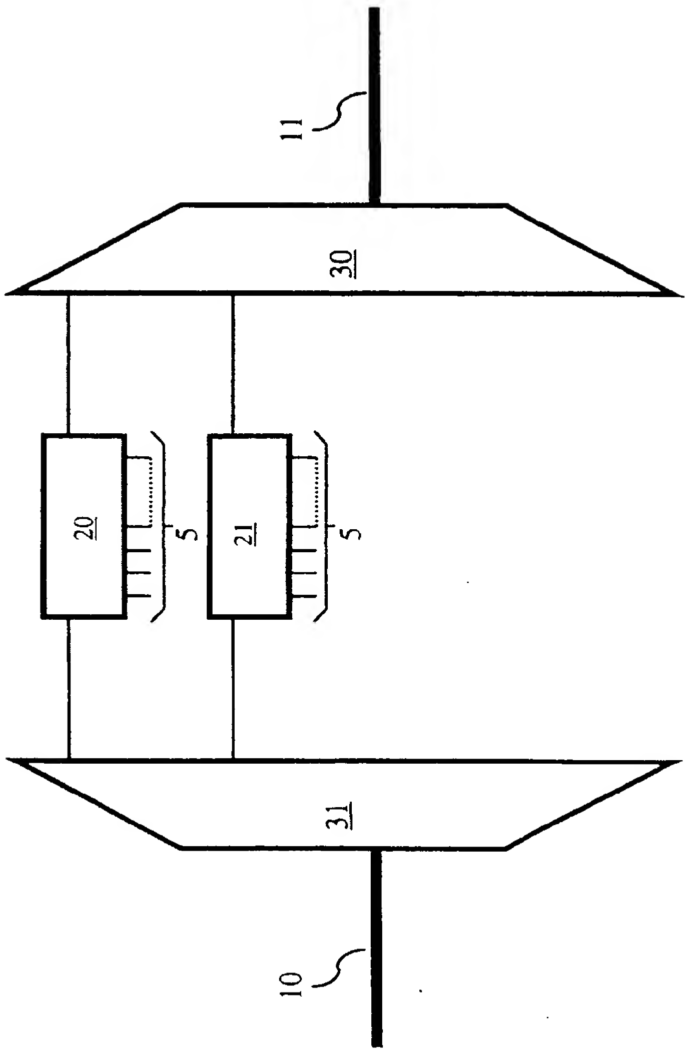

Fig. 3

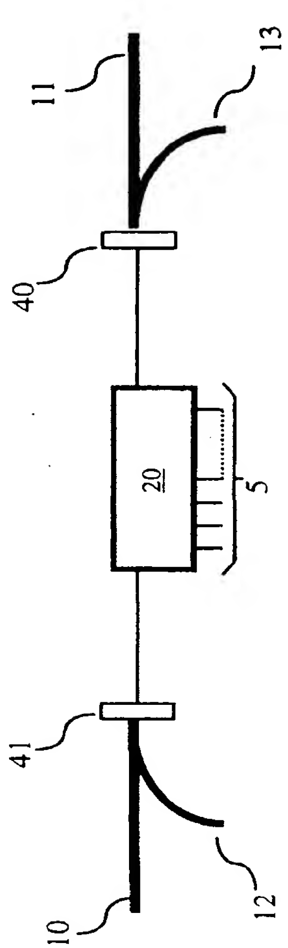

Fig. 4(a)

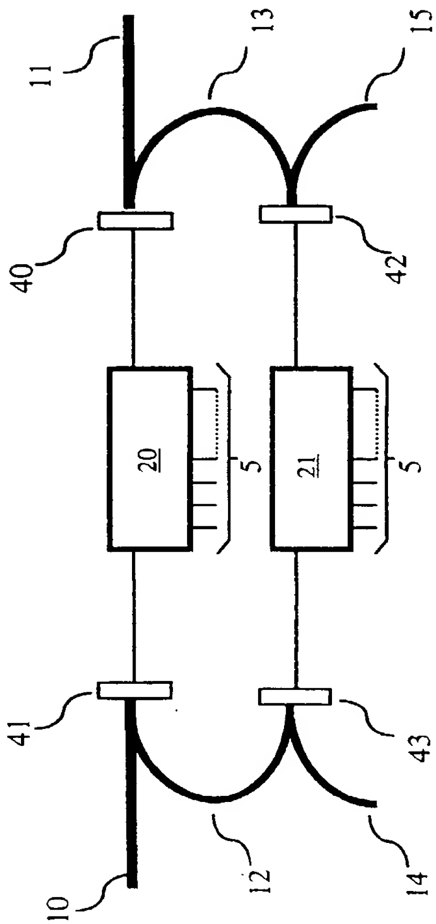

Fig. 4(b)

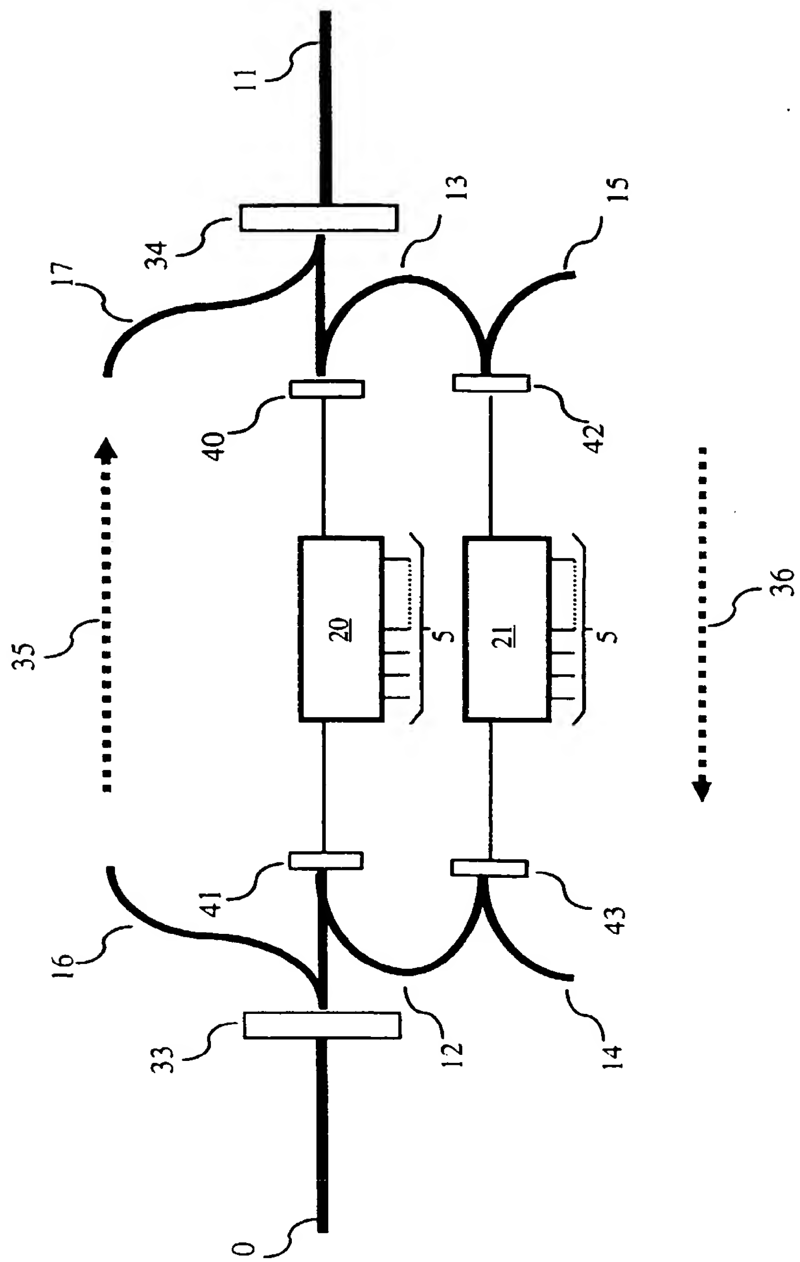

Fig. 5

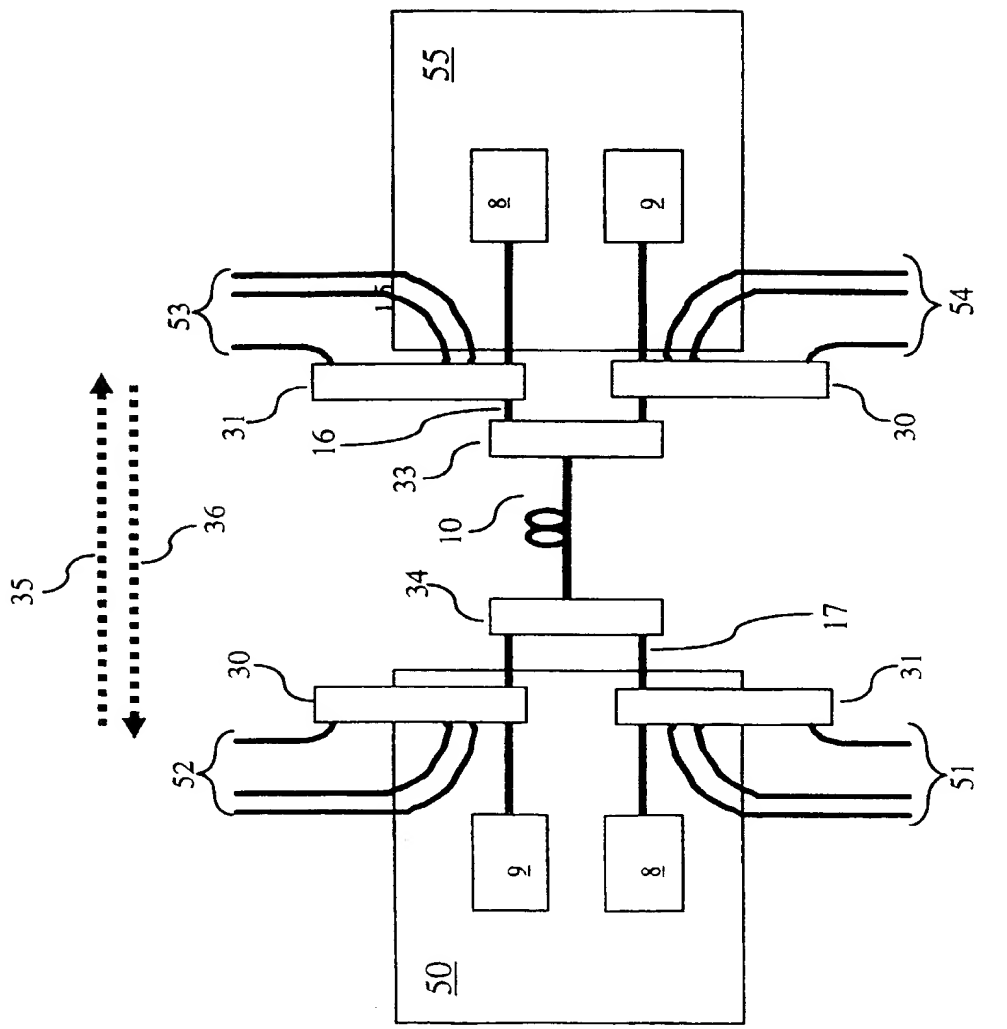

Fig. 6

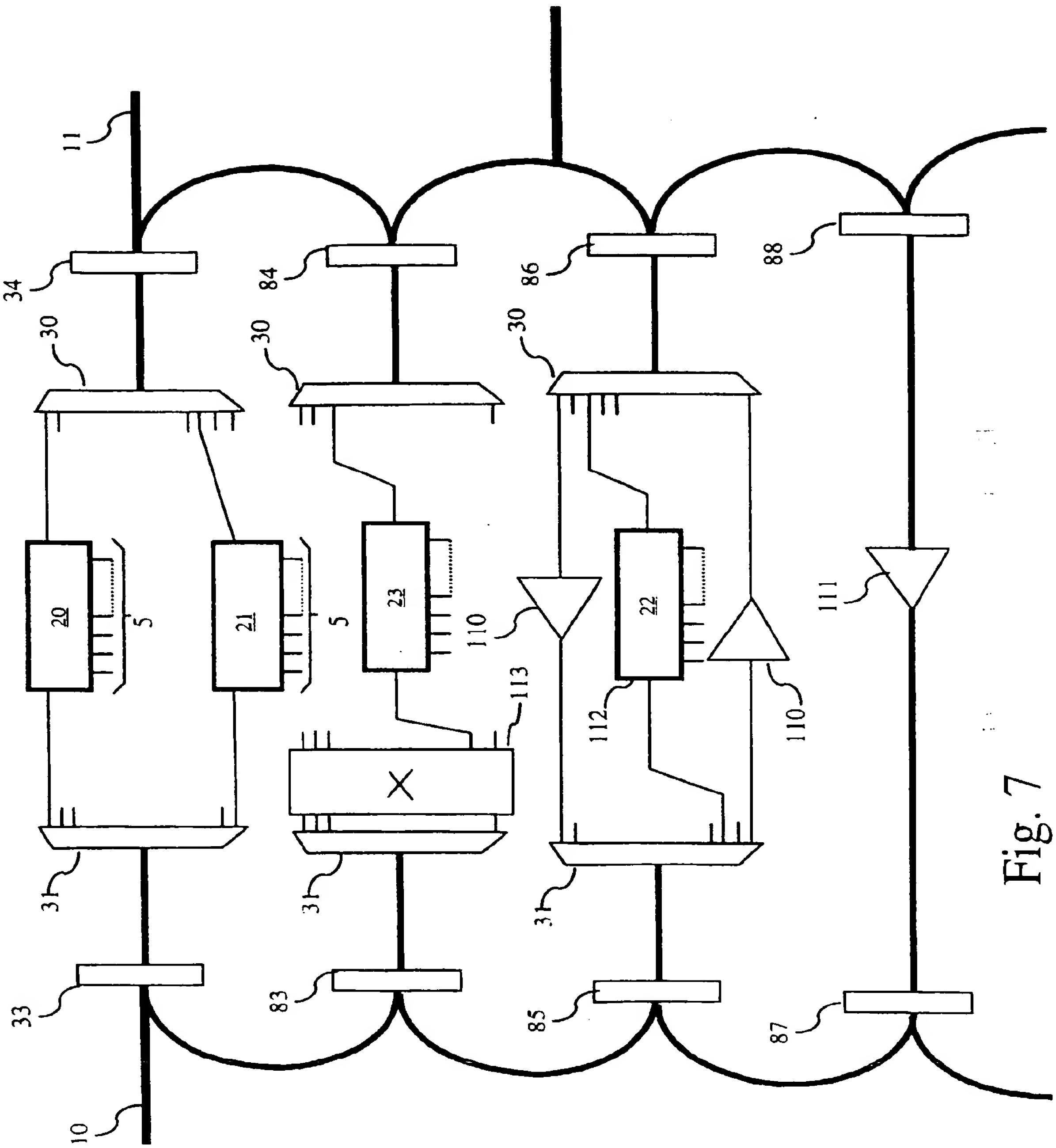
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Fig. 7

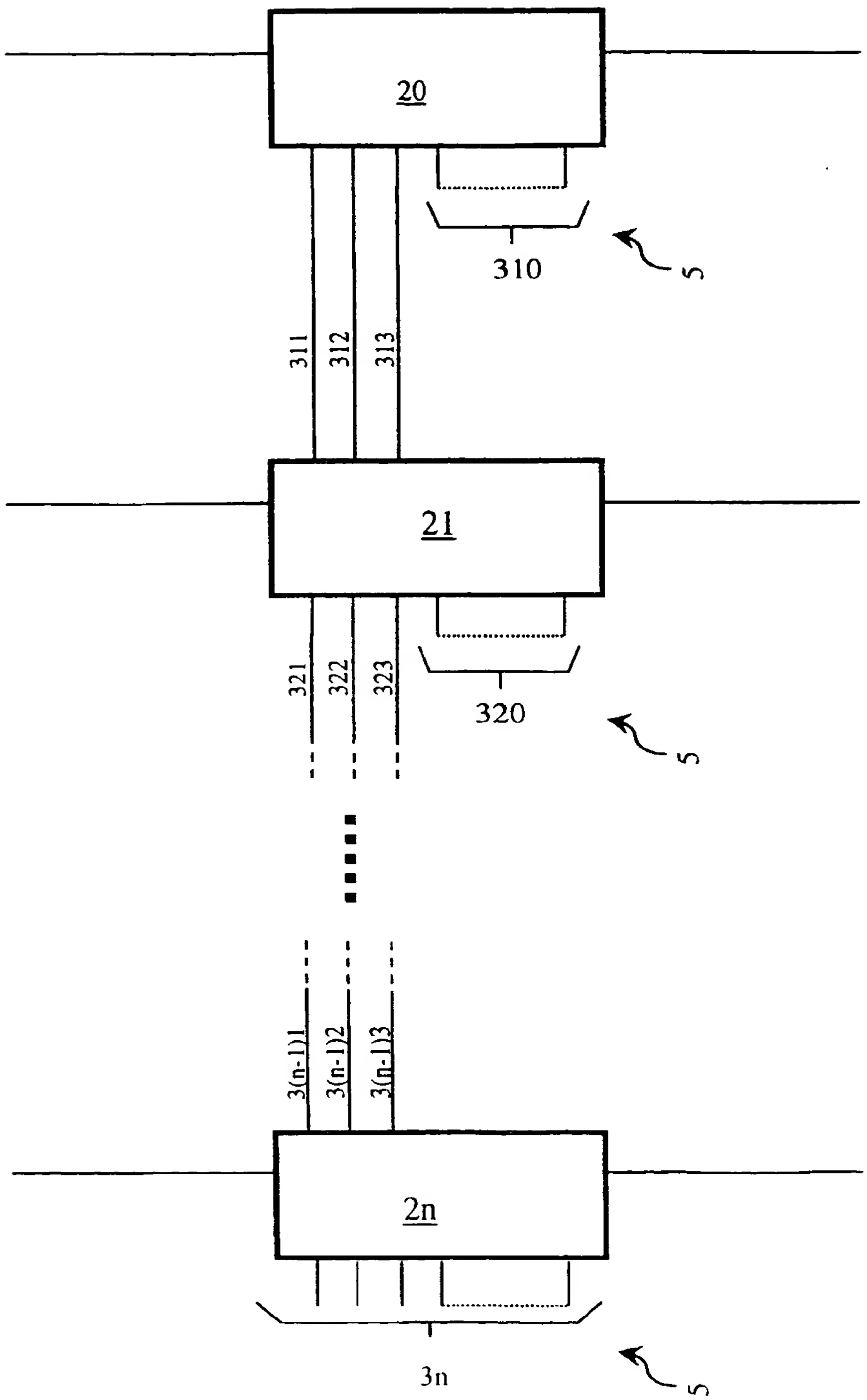

Fig. 8

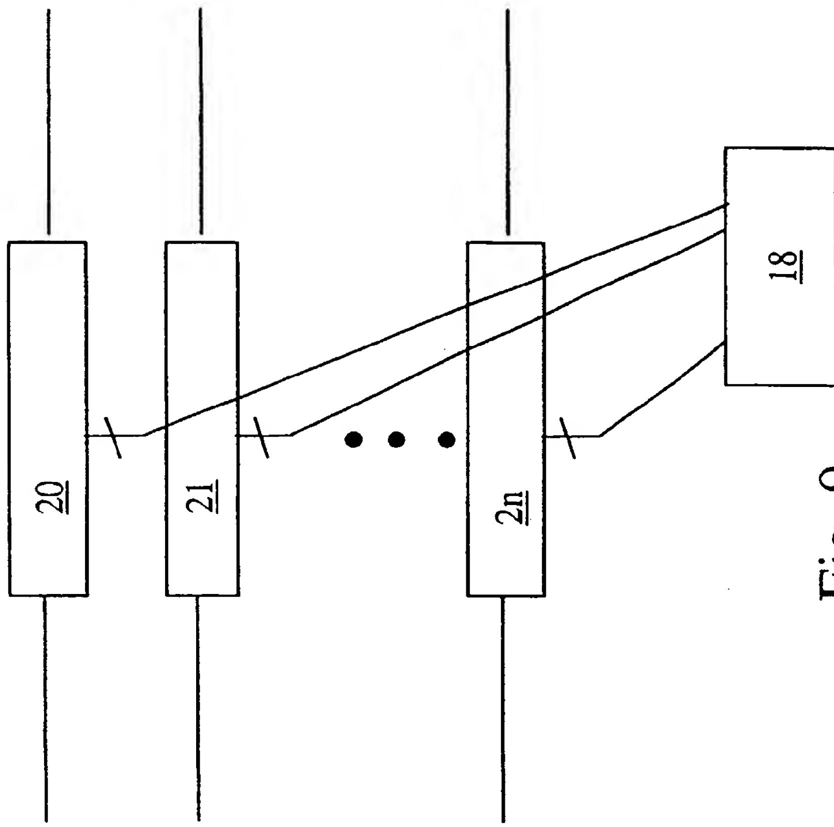

Fig. 9

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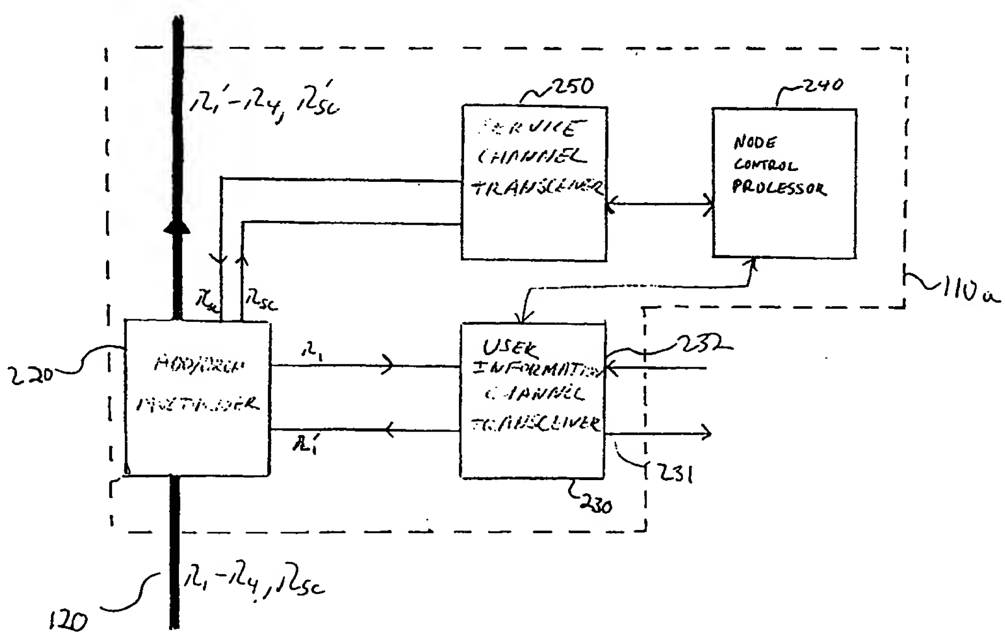

(57) Abstract

A WDM ring system is provided having a service channel at a wavelength different than the wavelengths associated with the user information channels. Accordingly, the service channel, which can carry diagnostic information related to the system, does not interfere or otherwise consume capacity reserved for the user information channels. Moreover, the present invention optionally provides a "short-reach" optical interface to external equipment, thereby avoiding costly optical regenerators.

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WDM RING HAVING AN OPTICAL SERVICE CHANNEL

BACKGROUND OF THE INVENTION

The present invention is directed toward a system for monitoring a wavelength division multiplexed (WDM) system having a ring configuration.

Optical communication systems are a substantial and fast growing constituent of communication networks. Currently, the majority of optical communication systems are configured to carry an optical channel of a single wavelength over one or more optical waveguides. To convey information from plural sources, time-division multiplexing (TDM) is frequently employed. In time-division multiplexing, a particular time slot is assigned to each signal source, the complete signal being constructed from the portions of the signals collected from each time slot. While this is a useful technique for carrying plural information sources on a single channel, fiber dispersion and the need to generate high peak power pulses limit its capacity.

While capacity can be increased by laying additional fiber, in certain locations, such as metropolitan areas, the cost of laying additional fiber is prohibitive. Point-to-point wavelength division multiplexed (WDM) systems have thus been deployed in which a single fiber can carry numerous optical channels, thereby greatly increasing the capacity of the fiber. In metropolitan areas, WDM systems having a ring configuration can be used to provide high capacity data links between several nodes.

In order to insure proper operation of a WDM system, in particular one having a ring configuration, the WDM system must be monitored for faults. Moreover, information related to system performance must be transmitted throughout the system without interfering with the transmission of user information data.

SUMMARY OF THE INVENTION

Consistent with the present invention, a communication system is provided comprising a node coupled to a closed optical path. The node includes a plurality of first optical emitters, each supplying a corresponding one of a first plurality of user information channels to the closed optical path. Each of the first plurality of user information channels has a respective one of a first plurality of optical wavelengths. The node further includes a plurality of first optical receivers, each for sensing a corresponding one of a second plurality of user information channels from the closed optical path. Each of the second plurality of user information channels has a respective one of a second plurality of optical wavelengths, which can be the same as or different than the first plurality of wavelengths.

The node also comprises a service channel transmitter and receiver. The service channel receiver receives the optical service channel from the closed optical path, and the service channel transmitter transmits an optical service channel on the closed optical path at a wavelength different than the first and second pluralities of wavelengths. The transmitted optical service channel carries first service information, and the received service channel carries second service information, which can include either the same or different system diagnostic information than the first service information.

The communication system also comprises a second optical receiver, which is coupled to the closed optical path, and configured to sense one of the first plurality of user information channels from said closed optical path. Additionally, a second optical emitter is coupled to the closed optical path, and supplies one of the second plurality of user information channels to said closed optical path.

BRIEF DESCRIPTION OF THE DRAWINGS

Advantages of the present invention will be apparent from the following detailed description of the presently preferred embodiments thereof, which description should be considered in conjunction with the accompanying drawings in which:

Fig. 1 illustrates a block diagram of a WDM ring system in accordance with the present invention;

Fig. 2 illustrates a block diagram of a node in accordance with the present invention;

Fig. 3 illustrates an optical add/drop multiplexer included in the node shown in Fig. 2;

Fig. 4 illustrates a user information channel transceiver included in the node shown in Fig. 2;

Fig. 5 illustrates a service channel transceiver included in the node shown in Fig. 2; and

Fig. 6 illustrates a user information channel transceiver in accordance with a further embodiment of the present invention.

DETAILED DESCRIPTION

In accordance with the present invention, a WDM ring system is provided having a service channel at a wavelength different than the wavelengths associated with the user information channels. The service channel does not interfere or otherwise consume capacity reserved for the user information channel, and carries information for maintaining the system. Such information includes, for example, diagnostic and/or telemetry data, as well as monitor and control data. Moreover, in an alternative embodiment, the present invention advantageously provides an inexpensive "short-reach" optical interface to external equipment, thereby avoiding costly optical regenerators at the external equipment.

Further, since the present invention comprises a WDM ring, each wavelength can accommodate a particular transmission protocol. Thus, a single optical fiber, constituting part of the continuous optical path of the present invention, can simultaneously support many different protocols and data rates such as OC3, OC12, OC48, 100BT or native ATM or Ethernet.

Turning to the drawings in which like reference characters indicate the same or similar elements in each of the several views, Fig. 1 illustrates a WDM ring or loop system 10 comprising plurality of nodes 110-a to 110-d, for example, coupled to a closed or continuous optical path 120. Each of nodes 110-a to 110-d is configured to transmit on and receive from closed optical path 120 a plurality of user information channels, each at a respective wavelength. In addition, nodes 110-a to 110-d transmit and receive a service channel at a wavelength different than the user information channel wavelengths. Although four nodes are shown in Fig. 1, it is understood that any appropriate number of

nodes can be provided along closed optical path 120 in accordance with the present invention.

Fig. 2 illustrates node 110-a in greater detail. It is understood that nodes 110-b to 110-d have a similar construction as node 110-a. Node 110-a includes an add/drop multiplexer module 220 coupled to closed optical path 120. In the example shown in Fig. 2, add/drop multiplexer 220 is configured to extract service channel λ_{SC} and a single user information channel, λ_1, while allowing remaining user information channels, λ_2-λ_4, to continue propagating along closed optical path 120. Channel λ_1 is supplied to user information channel transceiver 230, while λ_{SC} is fed to service channel transceiver 250. User information channel transceiver 230 detects the data carried by channel λ_1 and outputs this data as an optical signal through port 231. The diagnostic information carried by service channel λ_{SC}, however, is output by service channel transceiver 250 to node control processor 240. This information can then be used to apprise node control processor 240 of the status of system 10, for example, and can also be used to control user information channel transceiver 230, as discussed in greater detail below.

User data input to node 110a is typically supplied as an optical signal to user information channel transceiver 230 through port 232. The user data is next transferred to user information channel λ_1' (typically at the same wavelength as channel λ_1) by user information channel transceiver 230 and output to add/drop multiplexer 220, which, in turn, adds channel λ_1' to closed optical path 220.

Diagnostic information related to node 110-a, for example, is typically obtained by node control processor 240 through various monitoring functions. The diagnostic information is supplied as electrical signals to service channel transceiver 250, which

outputs the service channel λ_{SC}' (typically at the same wavelength as λ_{SC}, but carrying different information) to add/drop multiplexer 220 for input to closed path 120 and transmission to one of nodes 110-b to 110-d.

Although extraction and addition of a single user information channel by node 110-a has been described above, it should be understood that additional user information channels can be added and extracted at the same node. In which case, a user information channel transceiver is typically provided for each additional user information channel to be added and extracted from closed optical path 120. Moreover, for security purposes, node 110-a can be located remote from add/drop multiplexer 220, and service channel λ_{SC} can be split off at user information channel transceiver 232 or at some intermediate point between add/drop multiplexer 220 and user information channel transceiver 232. In which case, the multiplexers and demultiplexers used for combining λ_{SC} and the user information channel can be housed in a module separate from add/drop multiplexer 220 and user information channel transceiver 232.

Fig. 3 illustrates optical add/drop multiplexer 220 in greater detail. Optical add/drop multiplexer 220 comprises an optical add/drop component 310, as described, for example, in U.S. patent application entitled "An Optical Add/Drop Multiplexer" to V. Mizrahi, filed October 23, 1997, attorney docket no. 212, incorporated herein by reference. Optical add/drop multiplexer typically adds and drops channels in the optical domain without regeneration through optical-to-electrical and subsequent electrical to optical conversions. As a result, element 120 in Fig. 1 constitutes a continuous optical path.

Returning to Fig. 3, optical add/drop component 310 has a first port 311 coupled to closed optical path for receiving channels λ_1-λ_4 and λ_{SC}. A second port 312 of optical add/drop component 310, in this example, outputs channels λ_1 and λ_{SC} to optical demultiplexer 320. Port 321 of optical demultiplexer 320 outputs channel λ_1 to transceiver 230, and port 322 outputs service channel λ_{SC} to service channel transceiver 250.

Optionally, as further shown in Fig. 3, optical add/drop multiplexer 220 further includes an optical multiplexer 330, which receives channels λ_1' and λ_{SC}' through ports 331 and 332, respectively. These channels are combined at output port 33 and supplied to port 313 of optical add/drop port 313, which, in turn, adds channels λ_1' and λ_{SC} to closed optical path 120. If additional channels are to be added or dropped from the same node, a corresponding number of optical add/drop components are typically added, each of which being coupled to a respective user information channel transceiver, as noted above. Moreover, although optical multiplexer 330 and optical demultiplexer 320 are shown in Fig. 3 located within optical add/drop multiplexer 220, it is considered within the scope of the invention that these components can be positioned remote from optical add/drop multiplexer 220. Moreover, multiplexer 330 and demultiplexer 320 can be positioned at any point intermediate optical add/drop multiplexer 220 and user information channel transceiver 230 or within user information channel transceiver 230.

User information channel transceiver 230 will next be described with reference to Fig. 4. User information channel transceiver 230 includes a first input port 401 receiving user information channel λ_1, for example. Typically, a receiver 404, including a photodetector, for example, is coupled to first input port 401, which converts the received

optical signals into electrical signals. Receiver 404 further includes circuitry that performs clock and data recovery from these electrical signals. The output of receiver 404 is coupled to a two-way electrical splitter 406, for example, which couples the output of receiver 404 to switch 426 and optional forward error correction (FEC) circuit 410. Data contained in the output of receiver 404 is to be output from node 110-a couples receiver 404 with FEC circuit 410. FEC circuit 410 is described, for example, in U.S. patent application entitled "Remodulating Channel Selectors For WDM Optical Communication Systems" to S. B. Alexander et al., filed October 21, 1997 and incorporated by reference herein. Optionally, FEC decoder circuit 410 decodes and corrects any errors present in data output from receiver 404. The output of FEC decoder circuit 410 is coupled to transmitter 412, which includes an optical emitter, such as a 1.3 micron laser, for outputting optical signals to an optical network in an office building, for example. Since the optical signals output from transmitter 412 are typically transmitted over relatively short distances, transmitter 412 is termed a "short reach interface." Moreover, these optical signals can be in a Synchronous Optical Network (SONET) format. In which case, the transmitter 412 obviates the need for costly SONET regenerator circuits.

Optical signals are further received from the optical network through second input port 232. Such optical signals are typically at 1.3 microns and are supplied to receiver 414, which outputs electrical signals in response thereto. The optical signals can be at a variety of transmission speeds and formats, such as OC3, OC12, OC48, 100BT, native Gigabit or Ethernet. Accordingly, the present invention is both bit rate and protocol transparent.

Optionally, the electrical signals output from receiver 414 are next encoded by FEC encoder circuit 416, as described, for example, in the patent application to Alexander et al., *supra.*, which if coupled to laser driver circuit 418 by switch 426, supplies encoded electrical signals to laser drive circuit 418. Laser diode 420 is thus modulated by the output of laser driver 418 in accordance with the encoded electrical signals. Alternatively, laser diode 420 can be operated in a continuous wave (CW) mode and the output modulated with a Mach-Zehnder external modulator, as described, for example, in U.S. Patent No. 5,504,609, incorporated herein by reference. Typically, a coupler 424 supplies a relatively small fraction of light output from the laser diode 420 to wavelength control circuit 422 for adjusting the temperature, and thus the wavelength of light output from laser diode 420. The remaining light output from laser diode 420 is supplied to add/drop multiplexer 220.

It should be noted that in the absence of FEC circuits 410 and 416 electrical signals generated by receivers 404 and 414 are typically supplied directly to transmitter 412 and laser driver circuit 418, respectively.

User information channel transceiver 230 allows the user to route electrical signals generated by receiver 404 directly to laser driver 418. In which case, node control processor 240 outputs first control signals to microprocessor 408, which, in turn, outputs second control signals to switch 426 to couple receiver 404 to laser driver 418. Accordingly, laser driver 418 modulates laser diode 420 in accordance with electrical signals generated by receiver 404, which reflect the data received from closed optical path 120. The modulated output of laser diode 420, which is substantially the same as the optical input received from closed optical path 120, but in amplified, regenerated form, is

then placed back on closed optical path 120 via optical add/drop multiplexer 220. This feature may be useful in regenerating a relatively weak user information channel.

As shown in Fig. 6, in accordance with an alternative embodiment, switch 426 and electrical splitter 406 are omitted, and replaced by optical fiber 614 connected between couplers 610 and 612. In response to optical signals input from add/drop multiplexer 220 through port 401, receiver 404 outputs electrical signals, which are optionally decoded by FEC decoder circuit 410, to transmitter 412. In response to these electrical signals, transmitter 412 outputs further optical signals, which are supplied to receiver 414 via optical fiber 610. Receiver 414, in turn, outputs electrical signals corresponding to the received optical signals which are optionally encoded by FEC encoder circuit 416 and fed to laser driver 418 for modulating the output of laser diode 420. Thus, optical signals received through 401 are first converted to electrical signals, converted back to optical signals, converted back to electrical signals, and finally converted yet again to optical signals. As a result, the optical signals output from laser diode 420 are substantially identical to those received through input port 401, but are amplified and regenerated. The embodiment shown in Fig. 6 has a simpler construction, compared to the embodiment shown in Fig. 4, but cannot be readily reconfigured to receive signals from a network at port 232, as in Fig. 4.

Service channel transceiver 250 will next be described with reference to Fig. 5. Service channel λ_{SC} is typically supplied to a silicon photodiode (PD) 540 from add/drop mulitplexer 220. Photodiode 540, in turn, generates electrical signals, which are output to receiver 550, containing clock and data recovery circuits. Additional electrical signals are then output from receiver 550 to microprocessor 510, which extracts and appropriately

formats diagnostic information for output to node control processor 240. In response to such diagnostic information, node control processor 240 may actuate switch 426. Alternatively, the user can actuate these switches by supplying appropriate signals to node control processor 240.

Diagnostic information, for example, supplied by node control processor 240, which can be different than the diagnostic information transmitted on service channel λ_{SC}, is typically supplied to microprocessor 510, which outputs appropriate signals to laser driver 520. In response to these signals, laser drive 520 generates electrical signals of sufficient duration and magnitude to modulate laser diode 530. The optical signals thus output from laser diode 530 and supplied to add/drop multiplexer 220 reflect the diagnostic information supplied from node control processor 510. Typically, the optical output from laser diode 530, λ_{SC}', is at the same wavelength as λ_{SC}, and is generally within a range of 1260 to 1360 nm, while the user information channels are within a range of 1500-1650 nm. However, both service and user information channels can be within the 1500-1650 nm range (e.g., λ_{SC} can be at 1533 or 1565) or in the 1260 to 1360 nm range.

While the foregoing invention has been described in terms of the embodiments discussed above, numerous variations are possible. Accordingly, modifications and changes such as those suggested above, but not limited thereto, are considered to be within the scope of the present invention. For example, although a single fiber optical ring is illustrated in Fig. 1, it is considered within the scope of the invention that an additional continuous optical ring path can be provided interconnecting nodes 110-a to 110-d with the additional signals typically propagate in the second ring in a direction opposite the first ring.

What is claimed is:

1. A communication system comprising:

a node coupled to a closed optical path, said node comprising:

a plurality of first optical emitters, each supplying a corresponding one of a first plurality of user information channels to said closed optical path, each of said first plurality of user information channels having a respective one of a first plurality of optical wavelengths;

a plurality of first optical receivers, each for sensing a corresponding one of a second plurality of user information channels from said closed optical path, each of said second plurality of user information channels having a respective one of a second plurality of optical wavelengths;

a service channel transmitter for transmitting an optical service channel carrying first service information on said closed optical path including diagnostic information related to said communication system, said optical service channel being at a wavelength different than said first and second pluralities of wavelengths; and

a service channel receiver receiving said optical service channel carrying second service information from said closed optical path; and

a second optical emitter coupled to said closed optical path, said second optical emitter supplying one of said second plurality of user information channels to said closed optical path.

2. A communication system in accordance with claim 1, further comprising:

a second optical receiver coupled to said closed optical path, said second optical receiver configured to sense one of said first plurality of user information channels from said closed optical path.

3. A communication system in accordance with claim 2, wherein said node is a first node, said communication system further comprising:

a second node coupled to said closed optical communication path, said second node comprising said second optical receiver; and

a third node coupled to said closed optical communication path, said third node comprising said second optical emitter.

4. A communication system in accordance with claim 2, wherein said node is a first node, said communication system further comprising a second node coupled to said optical communication path, said second node comprising said second optical receiver and said second optical emitter.

5. A communication system in accordance with claim 1, wherein said node further comprises an add/drop optical component coupled to said closed optical path, said add/drop component comprising:

a first port being coupled to closed optical path, said first port being configured to receive said second plurality of user information channels and said service channel carrying said second service information from said closed optical path;

a second port being configured to supply said one of said second plurality of user information signals to a corresponding one of said plurality of first optical receivers and supply said optical service channel carrying said second service information to said service channel receiver;

a third port receiving said one of said first plurality of user information channels from a corresponding one of said plurality of first optical emitters, said third port further receiving said optical service channel carrying said first service information from said service channel transmitter; and

a fourth port coupled to said closed optical path, said fourth port supplying to said closed optical path said one of said first plurality of user information channels and said optical service channel carrying said first service information.

6. A communication system in accordance with claim 5, further comprising:

an optical demultiplexer having a first port coupled to said second port of said optical add/drop component, said first port receiving said one of said first plurality of user information signals and said optical service channel with said second service information, said optical demultiplexer further having a second port outputting said one of said first plurality of user information signals to said corresponding one of said first plurality of optical receivers, and a third port outputting said service channel carrying said second service information to said service channel receiver.

7. A communication system in accordance with claim 5, further comprising:

an optical multiplexer having a first port coupled to said corresponding one of first optical emitters and receiving said one of said first plurality of user information channels, a second port coupled to said service channel transmitter and receiving said optical service channel carrying said service channel information, and a third port configured to output said one of said first plurality of user information channels and said optical service channel carrying said first service channel information to said third port of said add/drop component.

8. A communication system in accordance with claim 1, further comprising:

a processing circuit coupled to said service channel transmitter and said service channel receiver, said processing circuit supplying said first service information to said service channel transmitter and receiving said second service information from said service channel receiver.

9. A communication system in accordance with claim 1, wherein said node further comprising:

a second optical receiver configured to receive first optical signals and generate first electrical signals in response thereto, one of said plurality of first optical emitters being coupled to said second optical receiver and supplying a corresponding one of said first plurality of user information channels in response to said first electrical signals;

a third optical emitter coupled to one of said plurality of first optical receivers, said one of said first optical receivers outputting second electrical signals to said third optical emitter in response to said one of said second plurality of user information channels, said third optical emitter outputting second optical signals in accordance with said third electrical signals.

10. A communication system in accordance with claim 9, wherein said one of said plurality of first optical emitters comprises a laser, said node further comprising:

a laser drive circuit coupled to said second optical receiver and said laser, said laser drive circuit supplying second electrical signals to said laser to thereby selectively actuate said laser and generate said one of said plurality of user information channels.

11. A communication system in accordance with claim 9, wherein said one of said plurality of first optical emitters comprises a laser, said laser being externally modulated in accordance with said first electrical signals.

12. A communication system in accordance with claim 1, wherein said first and second pluralities of user information channels have wavelengths within 1500-1650 nm, and said optical service channel has a wavelength within a range of 1300-1400 nm.

13. A communication system in accordance with claim 1, wherein said first and second pluralities of user information channels and said optical service channel have wavelengths within a range of 1500-1650 nm.

14. A communication system in accordance with claim 1, wherein said first and second pluralities of user information channels and said optical service channel have wavelengths within a range of 1300-1400 nm.

15. A communication system in accordance with claim 1, wherein said first and second pluralities of user information channels and said optical service channel are selected within the ranges of 1300-1400 nm and 1500-1650 nm.

16. A communication system in accordance with claim 5, wherein said node comprises a module, said module comprising said add/drop optical component, at least one of said plurality of first optical emitters and at least one of said plurality of first optical receivers.

17. A communication system in accordance with claim 5, wherein said communication system comprises a first module including said add/drop component, and a second module comprising at least one of said plurality of first optical emitters and at

least one of said plurality of first optical receivers, said first module being located remote from said second module.

18. A communication system in accordance with claim 6, wherein said communication system comprises a first module including said add/drop component, and a second module comprising at least one of said plurality of first optical emitters and at least one of said plurality of first optical receivers, said first module being located remote from said second module, and said optical demultiplexer being coupled between said first and second modules.

19. A communication system in accordance with claim 6, wherein said communication system comprises a first module including said add/drop component, and a second module comprising at least one of said plurality of first optical emitters and at least one of said plurality of first optical receivers, said first module being located remote from said second module, and said optical multiplexer being coupled between said first and second modules.

20. An optical device, comprising:

an add/drop multiplexer coupled to a closed optical path, said closed optical path carrying a plurality of user information optical channels, each at a respective wavelength, said add/drop multiplexer having a first port connected to said closed optical path, a second port outputting one of said plurality of user information optical channels, a third port receiving said one of said plurality of user information optical channels, and a fourth port coupled to said optical path supplying said one of said plurality of user information optical channels to said optical path;

a receiver coupled to said second port of said add/drop multiplexer, said receiver generating electrical signals in response to said one of said plurality of user information optical channels carrying first information;

an optical emitter coupled to said third portion of said add/drop multiplexer; and

a switching circuit coupled to said receiver and said optical emitter to selectively supply said electrical signals to said optical emitter, said optical emitter emitting said one of said plurality of user information channels in response to said electrical signals.

21. An optical device in accordance with claim 20, wherein said receiver is a first receiver, said optical device further comprising:

a second optical receiver configured to receive optical signals and generate third electrical signals in response thereto, said second optical receiver being coupled to said switching circuit, said switching circuit selectively supplying one of said first and third electrical signals to said optical emitter.

22. An optical communication device comprising:

an add/drop multiplexer coupled to a closed first optical path, said closed optical path carrying a plurality of user information optical channels, each at a respective wavelength, said add/drop multiplexer having a first port connected to said closed optical path, a second port outputting one of said plurality of user information optical channels, a third port receiving said one of said plurality of user information optical channels, and a fourth port coupled to said optical path supplying said one of said plurality of user information optical channels to said optical path;

a first receiver coupled to said second port of said add/drop multiplexer, said receiver generating first electrical signals in response to said one of said plurality of user information optical channels carrying first information;

a first optical emitter coupled to said first receiver and receiving said first electrical signals, said first emitter outputting optical signals in accordance with said first electrical signals;

a second optical communication path having a first end portion coupled to said first optical emitter and a second end portion;

a second receiver coupled to said second end portion to thereby receive said optical signals from said first optical emitter, said second receiving generating second electrical signals in response to said optical signals; and

a second optical emitter coupled to said second receiver and receiving said second electrical signals, said second optical emitter outputting said one of said plurality of user information optical channels to said third port of said add/drop multiplexer in response to said second electrical signals.

23. A communication system comprising:

a closed optical path;

a first optical emitter coupled to said closed optical path, said first optical emitter being configured to supply a first user information channel at a first wavelength and carrying one of a first transmission protocol and a first transmission rate;

a first optical receiver coupled to said closed optical path and spaced from said first optical emitter, said first optical receiver sensing said first user information channel;

a second optical emitter coupled to said closed optical path, said second optical emitter being configured to supply a second user information channel at a second wavelength and carrying one of a second transmission protocol and a second transmission rate;

a second optical receiver coupled to said closed optical path and spaced from said second optical emitter, said second optical receiver sensing said second user information channel;

a service channel transmitter coupled to said closed optical path for transmitting an optical service channel carrying service information on said closed optical path including diagnostic information related to said communication system, said optical service channel being at a wavelength different than said first and second wavelengths; and

a service channel receiver sensing said optical service channel.

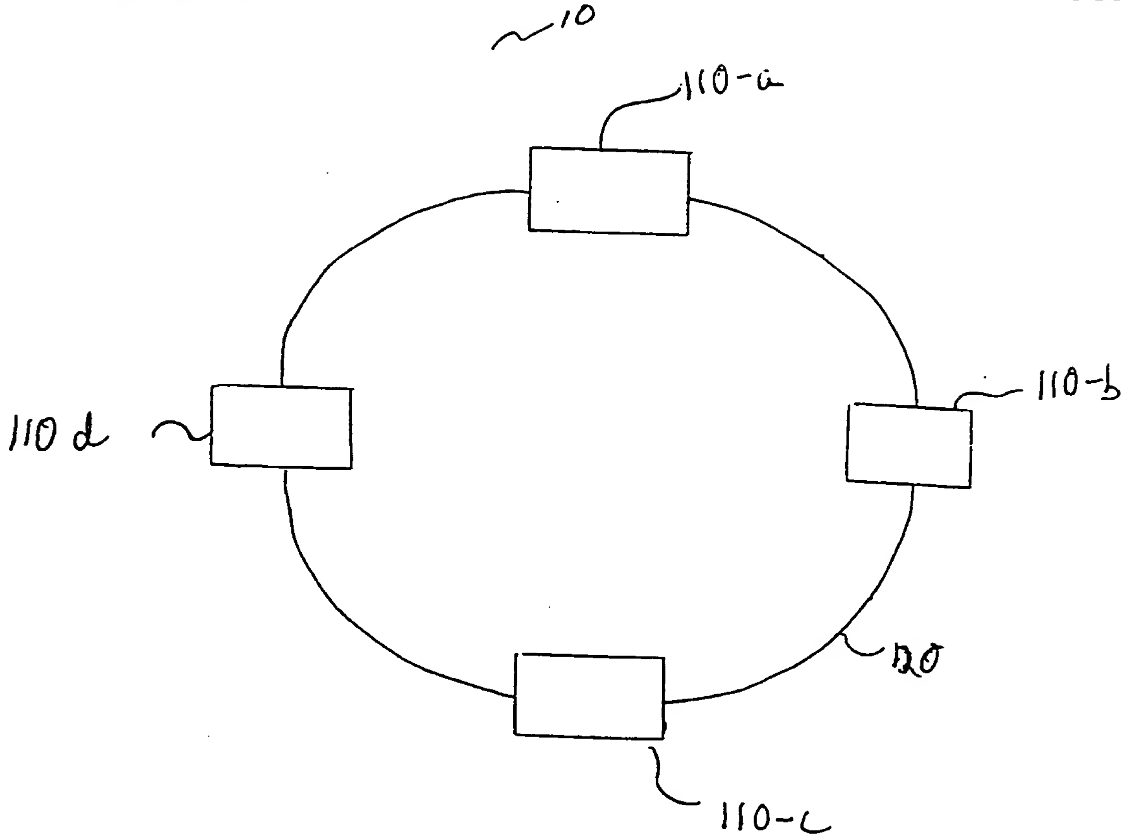


FIG 1

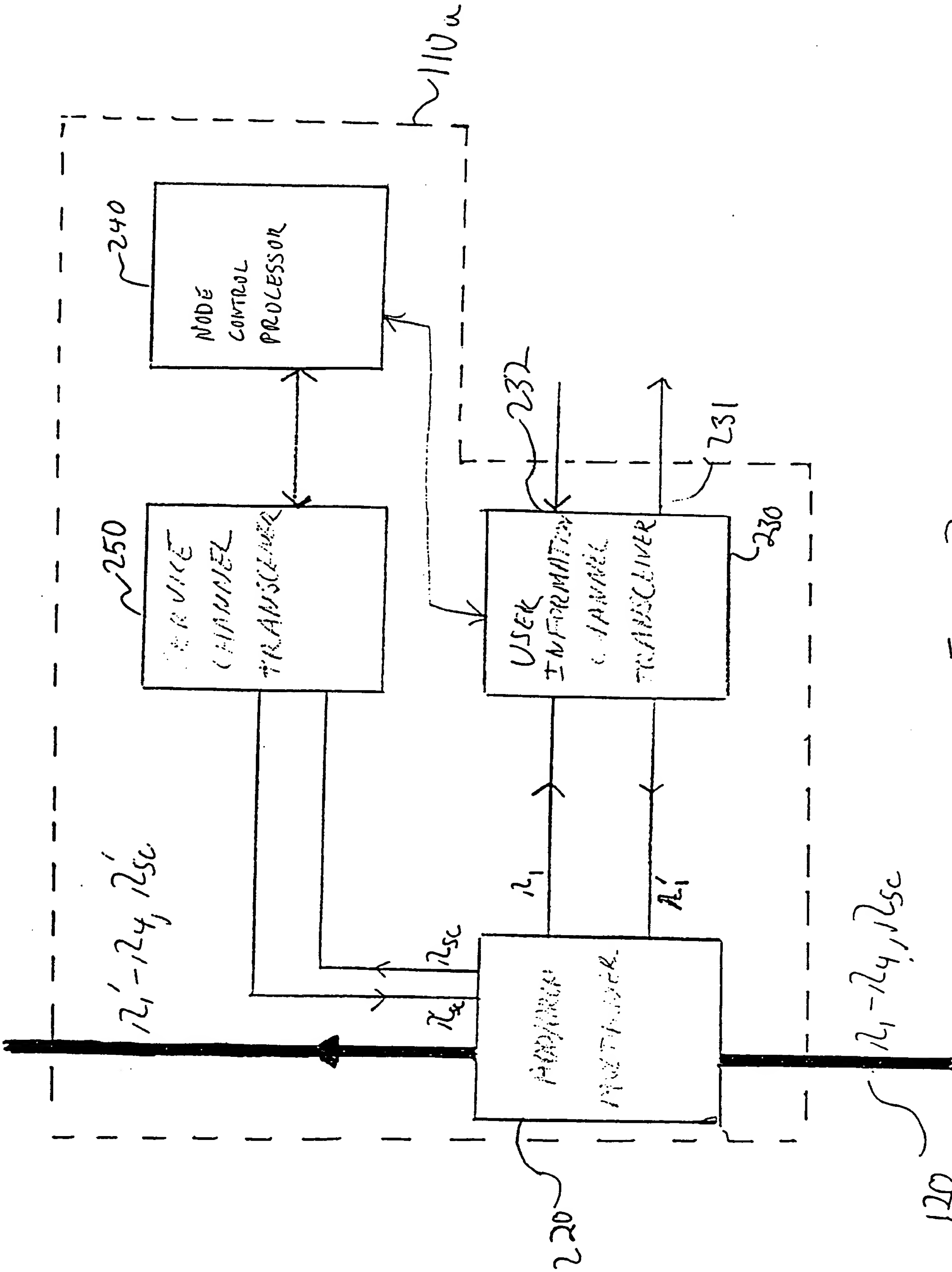
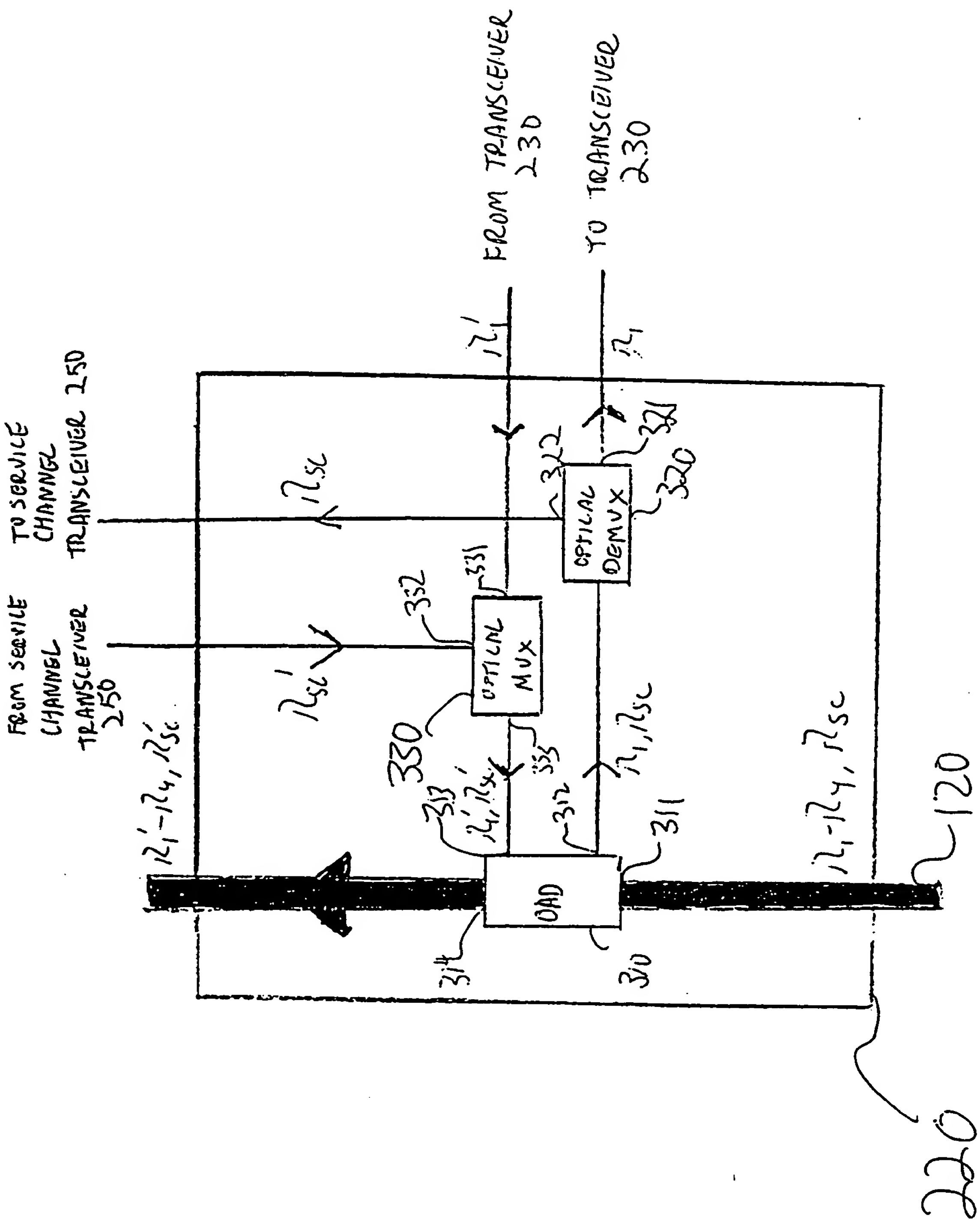


Fig. 2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TO TRANSCEIVER 230
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OPTICAL MUX
OAD
λ_1'
λ_1
λ_{sc}
λ_{sc}'
λ_1, λ_{sc}
$\lambda_1', \lambda_{sc}'$
$\lambda_1'-\lambda_4, \lambda_{sc}'$
$\lambda_1-\lambda_4, \lambda_{sc}$
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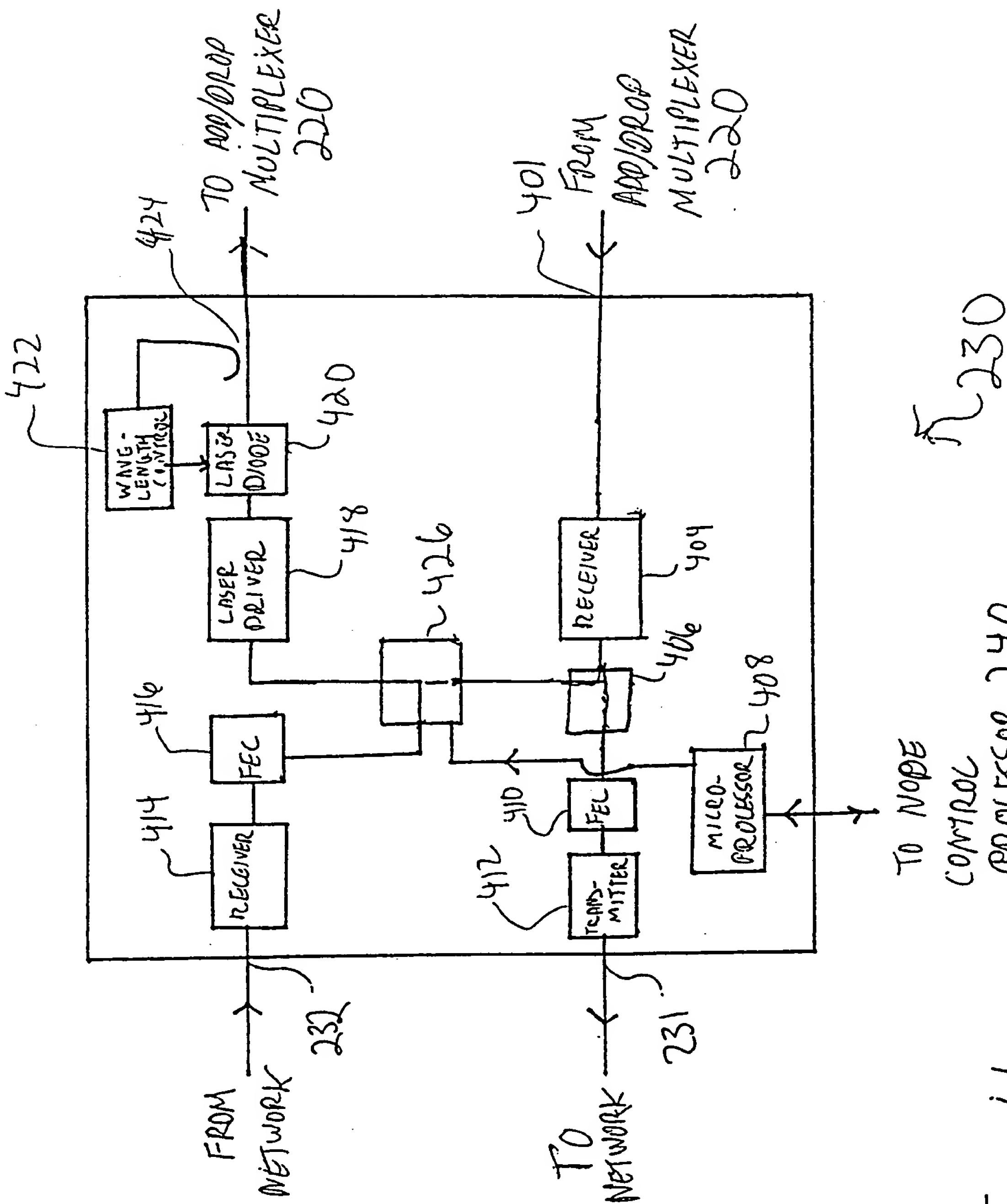
120
220

Fig. 3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401
FROM ADD/DROP MULTIPLEXER 220
424
422
WAVE-LENGTH CONTROL
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420
LASER DRIVER
418
426
RECEIVER
404
406
416
FEC
414
RECEIVER
410
FEC
412
TRANSMITTER
MICRO-PROCESSOR
408
TO NODE CONTROL PROCESSOR 240
230
FROM NETWORK
232
TO NETWORK
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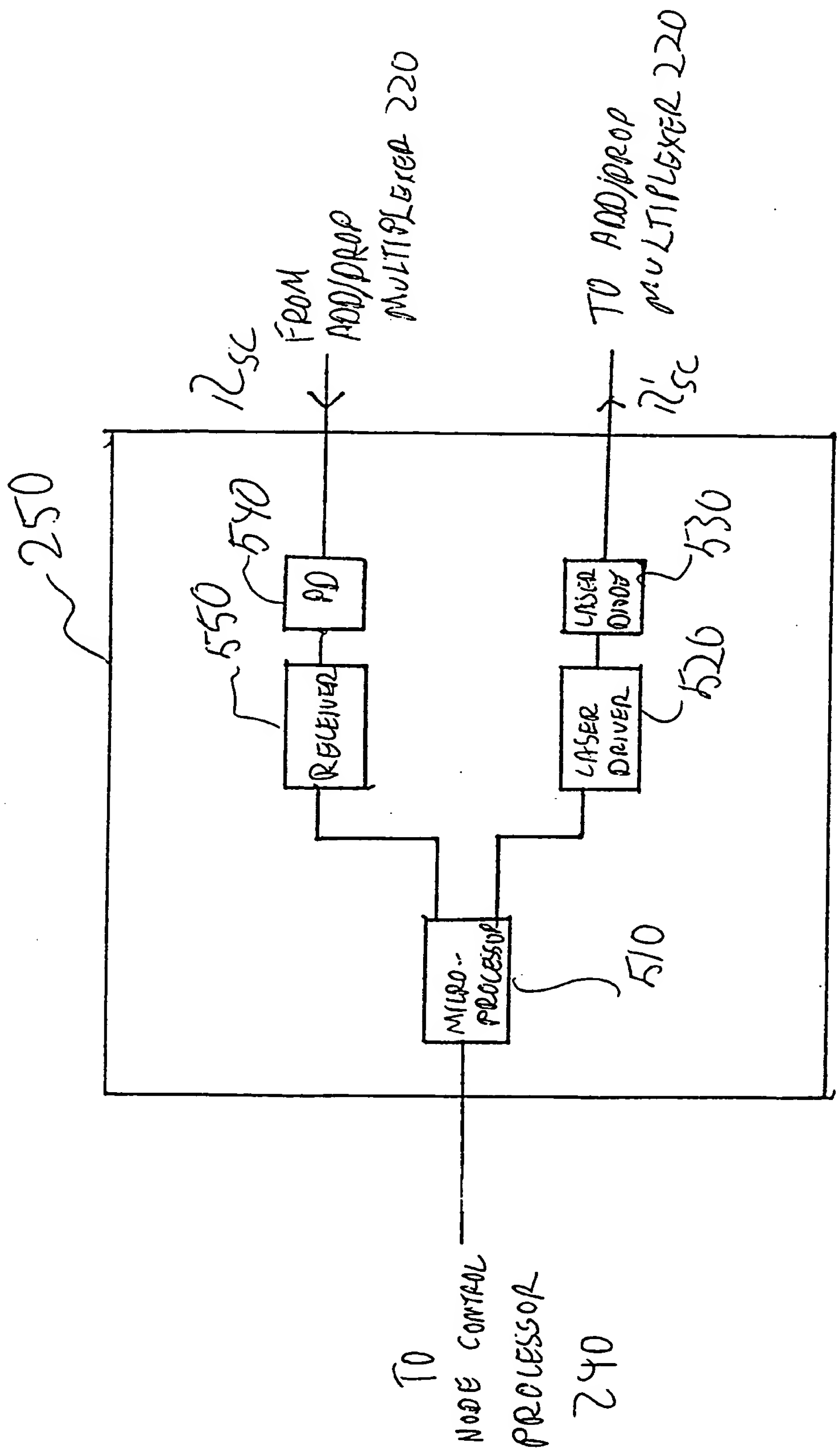
Fig. 4



250
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FROM ADD/DROP MULTIPLEXER 220
TO ADD/DROP MULTIPLEXER 220
λ'_{SC}
PD
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RECEIVER
LASER DIODE
530
LASER DRIVER
520
MICRO-PROCESSOR
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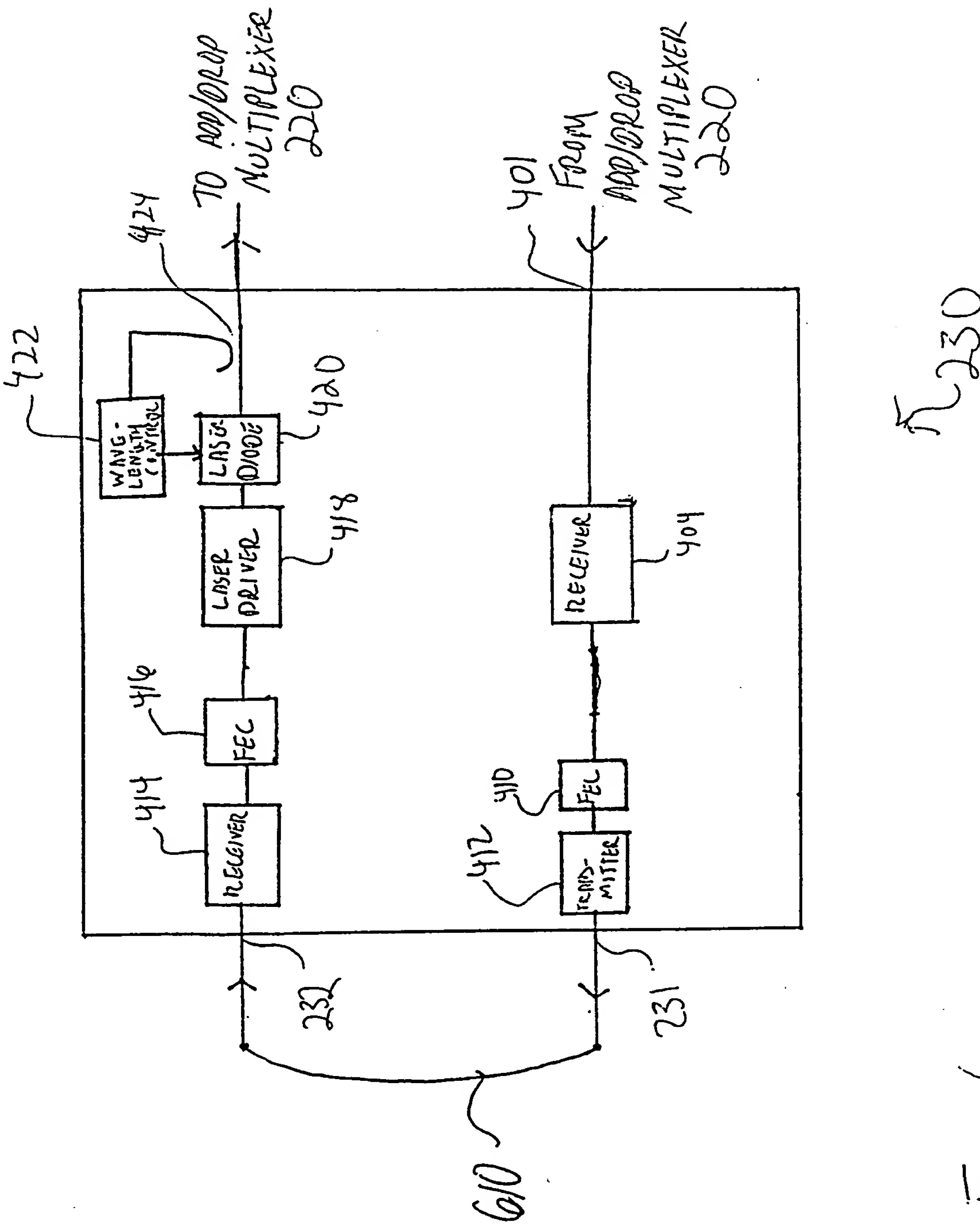
TO NODE CONTROL PROCESSOR 240

FIG. 5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FROM ADD/DROP MULTIPLEXER 220
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401
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WAVE-LENGTH CONTROL
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LASER DRIVER
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416
RECEIVER
414
RECEIVER
404
FEC
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TRANS-MITTER
412
232
231
610
230

Fig. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/02507

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04J14/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04J H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 0 769 859 A (PIRELLI CAVI SPA) 23 April 1997 see column 1, line 10 - line 21 see column 6, line 49 - column 7, line 42; figure 2 see column 8, line 3 - line 13 see column 8, line 39 - line 47 see column 10, line 6 - line 19 see column 12, line 48 - line 56; figure 5 ---	1-4, 12-15,23 5-8, 16-19

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 May 1999	01/06/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Roldán Andrade, J

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/02507

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	see page 6, line 10 - line 25 see page 7, line 25 - line 33 see page 8, line 18 - line 26 see page 13, line 1 - line 5 see page 13, line 18 - line 20; figure 2B see page 19, line 11 - line 22 see page 22, line 10 - line 12 see page 23, line 27 - line 30; figure 7 see page 38, line 6 - line 14; figure 15 ---	9-11,13, 15
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A	see column 1, line 3 - line 7 see column 7, line 37 - column 8, line 41; figures 4,7 ---	23
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